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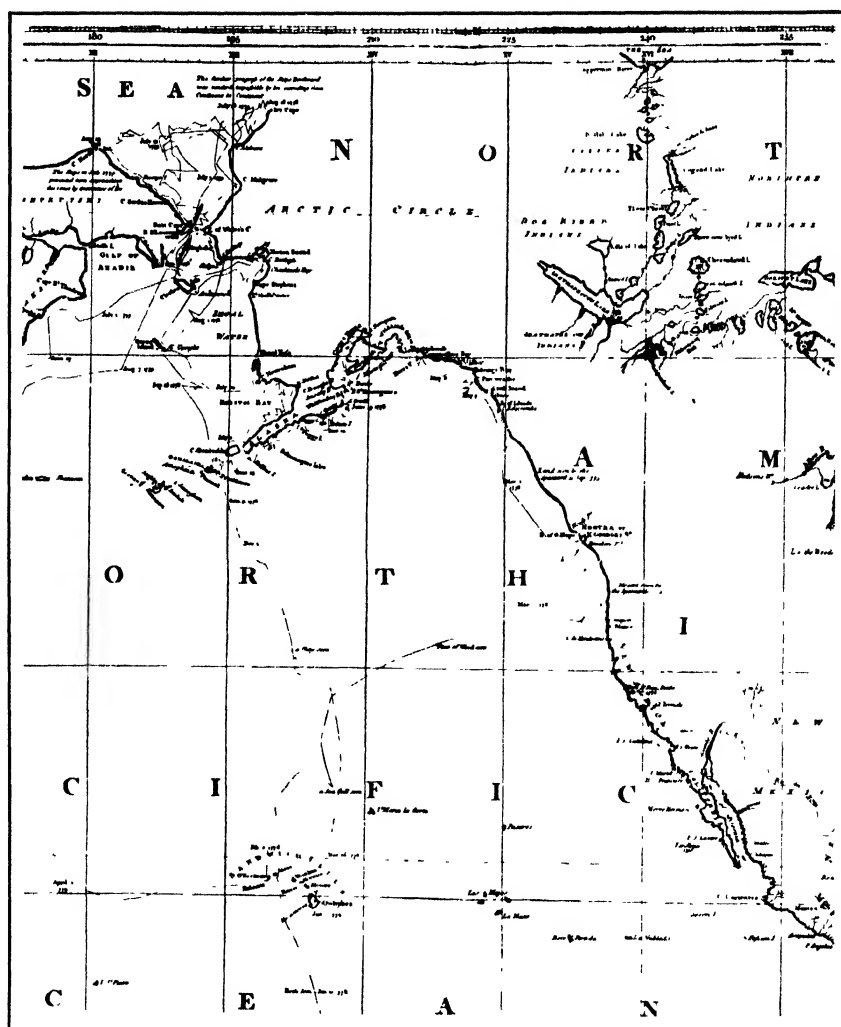
INDIAN AGRICULTURAL  
RESEARCH INSTITUTE NEW DELHI

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The Pacific Coast of North America from the original map of Cook

# Early Naturalists in the Far West

BY

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CALIFORNIA ACADEMY OF SCIENCES

1913

OCCASIONAL PAPERS NO. XX  
OF THE CALIFORNIA ACADEMY OF SCIENCES  
Issued April 30, 1913

COMMITTEE ON PUBLICATION

DR. F. M. MACFARLAND, *Chairman and Editor*

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# Early Naturalists in the Far West

## INTRODUCTION

IT HAS been said that observation is always the first in the trinity of scientific progress—philosophy and experiment must ever follow. Small wonder then that in this country natural science sprang from the labors of those adventurers who cast their glance to the sea, sky, and land in a never-ending search for the new. In the Far West this study had a unique birth and struggle for growth amid the shifting scene of nations striving for possession of the land. In nearly every case the expeditions of the Spanish, Russians, French, and English carried a man whose eyes sought not the depth of shoals nor the height of rocky headland, but the animate life which these bore—all to be recorded or, better still, collected for further study.

In this age of experimental science little attention is given by the modern biologist to the naturalists upon whose work his science is based. Too often does he take for granted their labors in making known the multitudinous variety and complexity of living things. Nearly every region of the earth's surface has been visited by the naturalist-explorer, and, in North America, the Pacific coast was one of the last of these physical frontiers for natural science as for civilization in general. It was rich in natural history as in other things: trees of incredible size and antiquity stood in dense forests sheltering countless forms of plant and animal life. Once tapped, this supply continued for a century to swell the herbaria and museums of the world and played a crucial part in the formulation of basic biological principles.

Stirred by the activities of foreign powers, our own country hastened its pace westward. Physical discomfort, scarcity of food, and the constant threat of Indian attack were the common lot of the naturalist-explorer; yet how cheap such a price for the seed of a plant unknown or a bird familiar only to the aborigines. Like the ant, these men, by the laborious accumulation of small particles, created a mountain. Lest we forget them and our debt to them, we have gathered, concerning some of these men, what information time and circumstance made possible. Because of the nature of the material

# NOVA PLANTARUM ANIMALIVM ET MINERALIVM MEXICANORVM HISTORIA

A FRANCISCO HERNANDEZ MEDICO

*Inchoata per plantarum summi recondituras.*

DEIN A NARDINO TORRICHO IN VOLUMEN DIGESTA

A IO. TERENCEIO, IO. FABRO, ET FABIO COLVATIA LINCIS

*Notis, & additionibus longe delictissimis illustrata.*

*Bibliotheca*

Cui demum accessere

*Veneranda 1683*

ALIQVOT EX PRINCIPALI FEDERICI CASII FRONTISPICIIS

*Tab. III. & IV. Physiognomice Tab. III.*

*Vna cum quamplurimis Iconibus, ad octingentas, quibus singula  
contemplanda graphice exhibentur.*



ROMAE MDCCL

Sumptibus Blasij Deuersini, & Zanobij Masotti Bibliopolarum.

Typus Vitalis Mascardi. Superiorum permisso.

and for the sake of brevity, no attempt has been made to weave a connected story.\*

The period covered is from the conquest of Mexico by Cortez in 1519 to 1840, when the era of rapid growth in the Far West had its inception. To the adventuresome spirits who, during these centuries, sought the biological treasures hidden in the ruggedness of the Pacific coast we now turn our consideration.

### THE AZTECS

The first naturalists in the West—probably in all North America—were the Aztecs. Upon his arrival in Mexico in 1519 Cortez might well have been amazed at the extensive botanical and zoological gardens (like none known in Europe at that time) which he found there, and had he been acquainted with the work of the encyclopedists in Europe he would have marveled at the systematic, nay, scientific arrangement of the material. But Cortez was there for other purposes.

There is much evidence that the Aztecs were well schooled in the science of medical botany, in fact, that it was a widely taught subject.<sup>60</sup> And one has but to examine their beautifully portrayed representations of the animals held captive to be convinced that they had an intimate knowledge of the zoology as well. As we shall presently see, Hernández, the first Spanish naturalist to visit this region, used many of the Aztec figures in his work on the natural history of the region.

The similarity of forms found in the aviaries and menageries to Old World forms led the Spaniards to confuse greatly the nomenclature set up by the Aztecs. If only a trained naturalist had accompanied Cortez, what a wealth of material and a wealth of sound ideas might have been made available to the scientific men of the day! But unfortunately the Spaniards had other pursuits to occupy their minds—they came as *conquistadores*, not as scholars.

### FRANCISCO HERNÁNDEZ

It is a sad commentary on the Spanish culture of the day that

\* We wish to express our appreciation to Professor L. L. Woodruff of Yale University for his helpful interest and encouragement during the preparation of this paper, and to Dr. S. W. Geiser of Southern Methodist University for his critical reading of the manuscript.

NOTE: Superior figures refer to Selected Bibliography.



throughout the early period of occupancy (1519–1700) of this region no systematic study of the flora and fauna was, to our knowledge, made, with the exception of an attempt by one Francisco Hernández (1514–1578) and Nardi Antonio Recchi.\* Francisco Hernández was apparently a man of some ability. We know that he was physician to Philip II of Spain and was sent to New Spain (1571–1577) by his sovereign. He and Recchi made an extended study of the region and, as noted above, utilized the work of the Aztecs—both their figures and their extensive collections, which fortunately Cortez did not destroy. Hernández apparently took great pains in the preparation of his material, but the work was not in print until long after his death; a portion was published in Rome in 1651, under the title *Nova Plantarum, Animalium et Mineralium Mexicanorum Historia*, but a complete edition was not compiled until nearly 140 years later (1790) from a manuscript found by Muñoz in the Madrid Jesuit College Library.

GEORG STELLER

Two centuries pass; then, far to the north, a striking young man of science, Georg Wilhelm Steller, began the work which gained for him the title of “The Pioneer of Alaskan Natural History.”\*\*

Born Sunday, March 10, 1709, in the free imperial city of Windheim, Georg Steller (originally Stoller) did not early show the extraordinary health and astounding energy that marked his later years, for we are told he was born with “no signs of life” and that some time passed before a lusty cry announced that the world was not to be cheated of the efforts of this most remarkable person.

Steller was to a great extent self-educated and assiduously prepared himself for his chosen work by studying, teaching, and tutoring at the University of Halle. About this time (1734) Russia, which had just successfully metamorphosed from a barbarous state into a first-rate power under the enlightened, if somewhat heavy hand of Peter the Great, was attracting much attention from the rest of

\* It should be stated that among those picturesque pioneers, the Jesuit missionaries, there were many who took a studied delight in the natural history of their New World surroundings. Such men as Kino, who by observing the distribution of plants and animals correctly surmised that California (Lower California) was not an island, and Crespi, and Inamnia, who made extensive experiments on the effects of rattlesnake poison, while not primarily naturalists, are deserving of the highest praise for their erudite observations.

\*\* Given him by Leonhard Stejneger in his excellent biographical account,<sup>80</sup> from which the greater part of this sketch is taken.

Europe. Before his death Peter the Great had completed plans for the establishment of an Academy of Sciences at St. Petersburg which was to be unique in its magnitude. His widow at once set about to bring this scheme to completion. It was not long before the adventurous spirit of Steller (coupled, no doubt, with the advice of his impressed professors) carried him to Russia to seek his fortune.

Interesting as it would be, we cannot further dwell on Steller's activities in St. Petersburg. Suffice it to say that Peter the Great had undertaken to ascertain the limits of his vast empire and had for this purpose sent an expedition, the Kamchatka Expedition, under Fleet-Captain Bering to explore the eastern terminus of his lands. After seemingly insurmountable difficulties, Bering returned only to find his results received by the authorities with ill-concealed skepticism. Angered by this, he offered to make a second voyage, which offer was accepted, and "The plan as finally developed by the Admiralty in 1732 amounted to nothing less than a nautical survey and mapping of the entire area of northern Asia and adjacent parts of America down to California."<sup>10</sup> Steller finally succeeded in getting himself attached to this Second Kamchatka Expedition as an "adjunct" under two other men of about his age, Gerhard Friedrich Müller and Johann Georg Gmelin, who were destined to become world famous.

After months of work in Siberia, Steller accepted Bering's offer to accompany him to America, and on June 4, 1741, the *St. Peter* left Avatcha Bay for the uncharted waters of the Pacific and Arctic oceans. Steller was not a retiring person, and his readiness to give unsought-for advice had often created a good deal of friction. The present voyage was no exception. The peculiar discipline which was then extant in the Russian outposts, a mixture of civil and military, irritated Steller, and during most of the voyage he was quarreling with his superiors, and usually in the wrong. He was constantly calling cloud-banks land, and for this the crew of the *St. Peter* gibed him unmercifully. Enjoying a good joke, but unable to take one on himself, he was tempting bait for their rough humor. Steller's constant attempts to interfere with the navigation of the ship does not speak well for his judgment and is an early example of what we shall later see took place on most expeditions where scientific men were a part; they failed to sympathize with the other aspects of the expedition. Fortunately, Bering was a man of parts and

seemed to realize that Steller suffered principally from over-enthusiasm.

Land was sighted early in July, and soon Steller became the first naturalist to set foot on Alaskan soil (Kayak Island). Oh the joys and miseries of that day! The curt announcement by Bering that he would set a course for home as soon as the water casks could be filled nearly drove Steller frantic. We know from his own words what was uppermost in his mind: "As soon as I . . . had landed . . . and realized how scant and precious was the time at my disposal, I seized every opportunity to accomplish as much as possible with the greatest possible dispatch." After collecting for six hours, he sat himself down "dead tired" and "made descriptions of the rarer plants which" he "was afraid might wither." Thus came into being *Catalogus plantarum intra sex horas . . . observatarum*—the first scientific paper on the natural history of Alaska,<sup>20</sup> and written on the spot—a model for modern explorers. Among the flora he described—in lengthy Latin, for this was some ten years before Linnaeus' introduction of binomial nomenclature—was the "salmonberry," *Rubus spectabilis*, which later (1811) was redescribed and named by Pursh from a specimen brought back by the Lewis and Clark Expedition from "the banks of the Columbia."

Late in the day, just before returning on board, Steller's collector placed in his hand a bird,

"... a single specimen, of which I remember to have seen a likeness painted in lively colors and described in the newest account of the birds and plants of the Carolinas published in French and English, the name of the author of which, however, does not occur to me now. This bird proved to me that we were really in America."<sup>21</sup>

But he couldn't remember the author's name! Is it not remarkable that this young scientist should have recollected the plate\* at all, that he should have noted it was more brilliantly colored than the bird he held, for the plate was of *Cyanocitta cristata*, and finally and most remarkable, that he should have adduced his position from the habitat of the bird? Only Steller's description of the bird, now known as Steller's jay, reached St. Petersburg, and in 1788 John Friedrich Gmelin named it, in honor of its discoverer *Cyanocitta stelleri*.

On his return trip to St. Petersburg—after being marooned for

\* Catesby's plate (Pl. 15, Eng. ed., 1731).

months on Bering Island—Steller died of “the fever.” Thus was cut short, far from home and friends, the life of one who gave every promise of being among the most useful scientists of all time.

There is much evidence of the sagacity of this youth. He was a “born collector,” said Linnaeus, and he was more than that, though when he died the scientific world knew him only as such. His few writings, produced, we must keep in mind, under the most trying conditions, showed he was not lacking in perseverance. His careful work of dissecting and describing the northern sea cow\* while marooned on an uninhabited island with a few survivors of the American trip who were anything but willing helpers, is a monument to scientific courage. His writings indicate he had an exceedingly sound idea of geographical distribution, and there is much which indicates he anticipated some of Lamarck’s ideas on environmental effects. That his work in the field of ichthyology is not wanting in excellence it attested by the words of Tilesius, written some sixty years later:

“Among Steller’s notes I have found our fish [Pacific codfish] not only accurately described, but even the structure and arrangement of its internal parts made clear by anatomical dissections and have discovered such an agreement between the observations by that keenest of observers and my own that it looked as if I had drawn my pictures for the purpose of proving the worth of Steller’s description.”<sup>90</sup>

Unfortunately the upset condition of the Russian Academy and the almost ridiculous precautions of the government to prevent any news of the expedition reaching its enemies brought about the dispersal of Steller’s collections and notes. As a result, his life work fell into other hands, often unscrupulous ones, and much of the credit which is due him has gone to others. One cannot but think, as did Linnaeus when he wrote on hearing of Steller’s death, “O bone Deus, quod tantum virum eripuisti!”<sup>91</sup>

#### COOK’S LAST VOYAGE

After the death of Steller, some thirty years elapsed before the shores of western America were again explored by a scientific party. In the year 1776, in the midst of its struggles with the American colonies and the wars on the continent, England prepared the vessels *Resolution* and *Discovery* for Captain Cook’s third and last voyage—

\* Steller was the only trained naturalist to see a live sea cow.

the only one touching western America. The first two voyages of this famous explorer had contributed such a vast amount to the knowledge of the Pacific region, as well as to the glory and interests of England, that the government was anxious to have him continue his work. In the realm of natural history the first voyage to the southern Pacific region was probably the most valuable. Sir Joseph Banks, naturalist to this expedition, was an ardent and omnivorous collector. His acquisitions added hundreds of new species of plants and animals to those known, including many of the interesting marsupials of Australia. Banks, however, did not choose to accompany Cook on either his second or his third voyage because of the lack of suitable accommodations.\* Instead, William Anderson, surgeon on the *Resolution*, served as naturalist for this voyage.\*\*

So on July 12, 1776, the *Resolution* set sail, and on August 1 the *Discovery* followed suit. It is interesting to note that despite the state of war, the American colonies, at the instance of Benjamin Franklin, ordered their fleet not to hinder the progress of the expedition. France and Spain issued similar orders, indicating the high esteem in which Cook's work was held.<sup>4</sup>

With the details of the voyage we cannot deal here. The expedition did not touch on the coast of western America until March of 1778. From Captain Cook's Journal<sup>5</sup> we learn of the versatility of Mr. Anderson as a naturalist. On one occasion we find him observing to the captain that there were two species of cockroaches aboard, *Blatta orientalis* and *Blatta germanica*; later on the voyage we find him naming a new species of crustacean, *Oniscus fulgens*; he was also familiar with many of the sea birds seen. Indications are that Anderson had a wide knowledge of natural history.

Concerning Anderson's life little is known. The place and date of his birth in England are not obtainable, nor do we know much about his early training. That he was known to botanists of the day is evidenced by the naming of the genus *Andersonia* after him by Robert Brown; and yet only two published papers of his are extant, one upon a poisonous fish<sup>6</sup> and the other a geological observation near Cape Town.<sup>3</sup>

But to return to the expedition. From March, 1778, to August of

\* Contrary to Stone,<sup>51</sup> who states that Banks was naturalist on the third voyage.

\*\* Dr. Newcombe<sup>60</sup> states that a David Nelson, who later accompanied Bligh on the *Bounty*, also collected botanical specimens on Cook's last voyage and that his specimens seemed to have become mixed with those of Menzies.

that year the vessels sailed from latitude  $40^{\circ} 30'$  north to Alaska. At Nootka, on the tip of Vancouver Island, the vessels put in, and here Anderson and Cook noted and collected some of the first recorded specimens of Pacific coast birds. Among these were the red-breasted sapsucker, the red-shafted flicker, and the junco. They also saw Steller's jay described so many years before. Anderson also mentions "... brownish water-lizards, with a tail exactly like that of an eel, which frequented the smaller standing pools about the rocks."<sup>20</sup> This undoubtedly was the Pacific newt, *Triturus torosus*, and probably his was the first recorded observation of this form, though it was not described for science until many years later.\* For the most part, however, the biological results of this expedition were rather disappointing. The failure of the expedition in this respect was due, no doubt, to the ill health of Anderson, who was suffering from tuberculosis, and off the coast of Alaska the unfortunate man died, August 3, 1778. His papers were left to Sir Joseph Banks. Of Anderson Cook said:

"He was a sensible young man, an agreeable companion, well skilled in his own profession; and had acquired considerable knowledge of other branches of science . . . and had it pleased God to have spared his life, the Public, I make no doubt, might have received from him such communications, on various parts of the natural history of the several places we visited, as would have abundantly shewn, that he was not unworthy of this commendation. Soon after he had breathed his last, land was seen to the Westward, twelve leagues distant . . . and, to perpetuate the memory of the deceased, for whom I had a very great regard, I named it Anderson's Island."<sup>21</sup>

The great explorer himself met death on this journey at the hands of the Sandwich Islanders on February 14, 1779. So ended the careers of these two—the one a world-renowned geographer, the other a promising student in the realm of natural history.

#### LA PÉROUSE'S VOYAGE

The publicity given to the English expeditions of Cook and Carteret in all probability directly led to the formation of the next expedition to the west coast of North America. In the year 1785 there sailed from France a finely equipped expedition under the

\* Described from the notes of Eschscholtz by M. H. Rathke in volume 5 of Friedrich Eschscholtz, *Zoologischer Atlas* (Berlin, 1829-1833), Part 5, p. 12, pl. XXI, fig. 15. This is the earliest work on California amphibia.

able command of Jean François Galaup de La Pérouse.\* Avowed purpose of the expedition was to explore further the remote regions of the earth in an effort to clear up moot geographical questions and to make observations and collections in the field of natural science. Two brigs, the *Boussole* and the *Astrolabe*, were detailed to the expedition, and a scientific staff of seventeen, among whom, it is said, were some of the most distinguished scientists of the day, accompanied it. On the *Boussole* were the Abbè Mongés, "regular canon of the French church, naturalist performing the functions of chaplain"; Collignon, botanical gardner; and Robert de Paul de Lamanon, natural philosopher and apparently a very able and hard-working man. On the *Astrolabe* natural history was placed in the hands of La Martinière, doctor of physic and botanist, the Père Receveur, again a naturalist performing the functions of chaplain, and Dufresne, naturalist.

La Pérouse first saw North America off Mt. St. Elias in Alaska on the twenty-third of June, 1786. He sailed along the coast, exploring the bayous and inlets for several weeks, then turned his ships southwards where he was kept at sea by a fogbound coast.

In mid-September of 1786 La Pérouse entered the harbor of Monterey. Ten days later he weighed anchor and headed out into the Pacific for the Orient. At Kamchatka and again at New Zealand La Pérouse had dispatches sent home, and for this caution we may well be thankful, for the expedition was never heard from again. These dispatches, among which were a few scientific monographs of a naturally sketchy nature, along with letters written by various members of the expedition, were published in 1797 in four quarto volumes with an atlas.<sup>50</sup> From this work we learn something of the progress of the voyage.

LaPérouse tells us that in spite of the advanced season while on the west coast of North America, the botanists carefully collected all possible seeds and plants, some of which were dispatched home.\*\* Nor was ornithology neglected, for he writes that many birds were seen and collected. Three are beautifully figured in the atlas, two of which are easily identified—*Perdrix de la Californie* and *Promerops*

\* Also spelled Lapérouse and Lapéviouse (Charles L. Bonaparte, *American Ornithology* [Philadelphia, 1828]).

\*\* La Martinière sent home seeds of a native (California) herbaceous plant (the Sand Verbena, *Thromia umbellata*?) which later matured and flowered (1797) at the Botanical Gardens

*de la Californie Septentrionale*, these being the California quail and the California thrasher.

"It was this early discovery that led Gambel, when he found and described the thrasher some sixty years later, to bestow upon it the name 'redivivus'—resurrected."<sup>53</sup>

From a letter over the signature of M. de Lamanon and dated January 1, 1787, we learn something of the man and of his colleagues. He writes:<sup>54</sup>

"I work more than twelve hours a day, and yet I am never beforehand in my work: fish to anatomize, quadrupeds to describe; insects to catch; shells to class . . . experiments to make; . . . and nature to contemplate—I would that for all this I could multiply my existence twenty times over."

And later:

"Mongés and myself have each our own province: his consists of birds, a portion of insects . . . and some objects of natural philosophy; mine includes geology, quadrupeds, fishes, shells and other aquatic animals. . . M. de la Martinière, who is on board the 'Astrolabe,' has the plants, and also amuses himself with insects, birds and fishes."

That La Martinière did "amuse" himself with insects is evidenced by a "Memoir Concerning Certain Insects" which fortunately reached France. He is here obviously out of his field, but is highly excited over polyps, siphonophores, nudibranch molluscs, and many other inhabitants of his bucket of sea water; remnants of echinoderms, possibly collected along the curving strip of beach of Monterey Bay, are also figured.

It is obvious from the published material appertaining to this expedition that up to its time it was certainly the most carefully planned and equipped voyage ever to hoist a sail; all advantage possible was taken of earlier expeditions, and an extensive library including maps, journals, and scientific monographs was on board. Directions issued by government and scientific bodies were minute. Many questions were postulated in print with the hope that an answer would be found during the journey around the world. Thus a current moot question in anatomy called for the following: "Il faudrait examiner si les cadavres, dans les pays où les hommes sont d'une très-haute taille, ont six vertèbres lombaires."<sup>55</sup>

So, with the fate of the *Boussole* and the *Astrolabe* went the larger part of the scientific results (and one of the earliest collections of the



flora and fauna of the north Pacific coast) of perhaps the finest expedition to sail under any flag.

#### THE MALASPINA EXPEDITION

Spain was to contribute the third important geographical and scientific expedition of the eighteenth century, planned by Charles III, but carried out during the reign of his successor, Charles IV. All precautions were taken to assure the success of the voyage, and two new vessels, the *Descubierta* and the *Atrevida*, were especially constructed for the purpose. Over one hundred officers, crew, scientists, and artists were placed under the command of Alexandro Malaspina, a native of Italy who sought foreign service as an adopted son of Spain. He was well equipped to command such an expedition, and the instructions given to his second-in-command are described as "a model of prevision, sagacity, prudence and wisdom."<sup>36</sup>

The two corvets put to sea from Cadiz July 30, 1789. Most of two years was spent in South and Central America. It was while at Acaapulco that Malaspina received orders to make a search for the mythical northwest passage. Although convinced of the futility of the venture, he set sail on the first day of May, 1791. The ships spent the summer prowling along the coast of Alaska and southward, eventually reaching the supply station at Nootka. The naturalists explored the surrounding territory and discovered they were on an island and not on the mainland, as had been supposed.

Leaving Vancouver Island August 28, 1791, the expedition proceeded southward along the coast. In spite of the fog they located, but did not enter, San Francisco Bay and on September 13th anchored off the Presidio in the Bay of Monterey. Malaspina was greatly taken by the region and noted that the abundance of wild life in the waters and along the shore "are very convenient for the exhaustless studies of the naturalist. Certainly," he adds, "it is difficult to find another place better adapted to" research in zoological and botanical fields.<sup>35</sup> The justness of these observations has since been strikingly affirmed by the establishment here of the Hopkins Marine Station for biological research.

Upon Malaspina's return to Spain his frank criticism of the government's misrule in her New World possessions led to his arrest and imprisonment in 1795. Eight years later he was released, but only on the condition that he leave Spain forever. This visitation of

a despot's rancor was directed not alone at Malaspina, but was extended likewise to all members of the expedition, with the result that none of the carefully prepared reports was published by the government.<sup>55</sup>

Among the scientists of the Malaspina expedition one man is remembered as an outstanding contributor to the success of the voyage—the Bohemian botanist, Thaddeus Haenke.<sup>56, 59</sup> He was born in Kreibitz on October 5, 1761. He received his early education from an uncle, a theologian, and then matriculated at the University of Prague where he received his Ph.D. degree at the age of twenty-one. He turned next to the study of medicine, but continued his botanical work, inspired by the botany professor in the university, Joseph Godfried Mikan. He published his Bohemian botanical studies as a "Flora of Sudetic." At the age of twenty-eight, by order of the Emperor, Joseph II, Haenke joined the Malaspina expedition as one of the botanists. Missing the sailing from Spain, Haenke met the party in Santiago. While en route there, he was shipwrecked on the west coast of South America, and all he was able to save of his carefully prepared equipment was the botanists' bible, a copy of Linnaeus.

Haenke collected at San Blas, Monterey, Port Mulgrave, and Nootka and also accompanied the expedition to the Philippine Islands. He returned to South America and settled at Cochabamba, from which place he made numerous collecting trips throughout the region. Because of his ability to understand the natives, he often conducted diplomatic missions for the King of Spain. In his own region he was loved by the natives, to whom he was physician, protector, and minister. Throughout the years he was planning always to return to his home in Bohemia, but he never lived to do so, for he was killed by accidental poisoning in the year 1817.<sup>60</sup> His collections are now at Madrid and Prague. Because of misplaced labels many of the plants of Asia were erroneously attributed to California or Chile.

Also connected with the Spanish expedition and charged with making a study "de las plantas y de sus aplicaciones"<sup>70</sup> were Martín Sessé and José Mariano Mocino. The latter botanized along the Pacific coast from Mexico to Nootka on Vancouver Island at the same time that Menzies made his second trip. Mocino also collaborated with Sessé in Mexico, and the results were published in "Plan-



Archibald Menzies From the painting by Eddis in  
the Linnaean Society, London

tae Novae Hispaniae"<sup>79</sup> and "Flora Mexicana."<sup>80</sup> In his journal of Vancouver's voyage<sup>81</sup> Menzies says:

"There were two Botanists attached to the Spanish squadron who visited the coast this summer, one of them then had been in the Aranzaza to the Northward and had made a considerable Collection of Plants from the different places they touched at, the other whose name was Don José Mozino remained at Nootka with Sr. Quadra together with an excellent draughtsman Sr. Escheverea,\* a Native of Mexico, who as a Natural History Painter had great merit. These told me that they were a part of a Society of Naturalists who were employed of late years in examining Mexico and New Spain for the purpose of collecting Materials for a Flora Mexicana which they said would soon be published, and with the assistance of so good an Artist it must be a valuable acquisition."

Mociño apparently did excellent work, but fortune was not with him, and his labors never received full recognition. He was prevented from working on his collections by the French invasion of 1808. During the war he took refuge in Switzerland but returned to Barcelona where he died in 1819. Most of his drawings were lost.

Another member of the Malaspina expedition, also a botanist, was Luis Née,<sup>82</sup> concerning whom little information is available. He evidently collected with Haenke, but whether he accompanied the expedition to the northwest coast is not certain.\*\* He described the Coast Live Oak (*Quercus agrifolia*) and the Valley Oak (*Quercus lobata*) from specimens collected at Monterey."

#### ARCHIBALD MENZIES

As La Pérouse shaped his ill-fated course from Monterey, a young Scotch botanist was rejoicing at receiving the appointment of surgeon on the *Prince of Wales*, commanded by Captain Colnett. Although the purpose of the voyage was fur-trading, Archibald Menzies hoped to be able to bring home some "curiosities" and asked his friend and patron Sir Joseph Banks to intercede for him, which the latter successfully did, familiar already with the abilities of this avid young collector. The voyage occupied three years and was Menzies' first trip to western North America.† Menzies apparently kept no diary of this trip, and little is known of the expe-

\* Correct spelling "Escheverria."

\*\* For brief biography see *Encyclopedia Universal Ilustrada* (Barcelona, 1905)

† According to some,<sup>82</sup> Menzies visited the northwest coast in 1779. We found no evidence to support this contention.

dition. It sailed from the Straits of Magellan directly to Nootka, arriving in July, 1787, with some of the crew down with scurvy. We can imagine Menzies hurrying ashore for his precious herbs, which he knew would stay the disease, as Steller had done in Alaska nearly half a century earlier for the same reason.

Archibald Menzies\* was born at Weems, Perthshire, Scotland, and was baptized on March 15, 1754. Many, if not most, of his forebears were either gardeners or botanists (there was often little to distinguish between the two at that time), and when he left home he went to Edinburgh and entered the Royal Botanic Garden as a student. Through the kindness and interest of one Dr. John Hope, Menzies also studied for the medical profession. Some years later—after a botanical tour of the Hebrides, several expeditions into Scotland, and some experience as assistant surgeon in the Royal Navy—Dr. Hope, in a letter of introduction to Sir Joseph Banks, says:

“Mr. Archibald Menzies was early acquainted with the culture of plants and acquired the principles of botany by attending my lectures . . . He has been several years on the Halifax Station in His Majesty's service as a surgeon, where he has paid unremitting attention to his study of botany. . . .”<sup>90</sup>

The trip of the *Prince of Wales* gave Menzies further experience. When he had thus attained some reputation, the British Government appointed him as naturalist to accompany Captain Vancouver in the *Discovery*. We get some idea of how Menzies came to be with Vancouver and also something of his temperament by his following words:

“At this time [1790] I had been upwards of twelve months retained by the Government to go out as Naturalist on [an] expedition planned for Capt. Roberts, but as a state of tedious suspense was more intolerable to me, than the hardships of a long Voyage or the dangers of traversing the wildest Forests, I requested leave of the Treasury to go out as Surgeon on the *Discovery*. . . .”<sup>91</sup>

He was appointed naturalist after some difficulty, and due to the illness of the surgeon was asked to serve in this capacity also. Vancouver<sup>92</sup> speaks well of his skill, stating that not a man was lost from ill-health during the entire voyage—truly extraordinary for the time.

\* The facts of this biographical sketch are taken principally from J. Forsythe's note in the preface to *Menzies' Journal*

Menzies' instructions were carefully issued by Sir Joseph Banks and consisted of orders to investigate the entire natural history of the countries visited. A glass case was constructed on the quarter-deck for such plants as could not be propagated by seed. Birds, beasts, and fish of commercial importance were to be noted. The sea otter—numerous and highly valued—was to receive particular attention; later Menzies wrote<sup>9</sup> on the anatomy of this once common member of the Pacific fauna. Menzies was also to note customs, manners, religion, etc., of the natives. A record of all collections and observations was to be kept and delivered to H.M. Secretary of State.

Vancouver was instructed to give all possible assistance to Menzies, and, while on the whole the two men seemed to have been on good terms, the latter was once placed under arrest for "insolence and contempt"—for objecting to having his assistant\* placed before the mast. Though Vancouver's work is second only to Cook's, there seems little doubt but that he was indiscreet at times and often exceeded his just powers. Menzies, though an older man (thirty-six in 1790) and in a position sharply contrasting to those around him, seems to have got on well with the crew, sharing hardships cheerfully when they could not be avoided.

The *Discovery* was off the coast of California in April, 1792, and Menzies excitedly noted evidence of near-by land and exhibited the greatest joy at finding "a most beautiful species of *Oniscus*" which he described as new, but which nearly certainly was the same as seen by Anderson of Cook's last voyage. Plover, medusae, ducks, and seaweed all occupied his attention, and his knowledge of them seems strikingly detailed. He secured specimens of the California vulture and quail later described by Shaw (1798).<sup>10</sup> At Nootka Menzies heard of the Malaspina expedition and crossed paths with, but apparently did not meet, José Mocño. Menzies sailed for the Sandwich Islands, but returned to California in 1793, where he collected widely from Bodega to San Diego and on southward. He gave freely of his collections, yet it was many years before they were adequately described and recorded by Sn J. E. Smith, R. A. Salisbury, Esper, Turner, Acharius, Pursh, and A. B. Lambert. Unfortunately, Pursh, while writing his *Flora Americae Septentrionalis*, had the collections of Lewis and Clark, and these he described before Menzies', and as a result some types are attributed to these explorers which Menzies

\* Probably one John Lums, listed as "Botanist's L. t."

had seen a decade earlier.\* Sir W. J. Hooker also worked on Menzies' collections some years later (1830), the bulk of them appearing in his *Flora Boreali-Americana* (1829-1840).

We shall see later that Douglas and Scouler profited greatly by Menzies' work and fully appreciated his assiduity and as pointed out by Newcombe,<sup>60</sup> though Menzies lost in many instances first honors of discovery due to Pursh's earlier description of the Lewis and Clark collections, yet he also gained by the misfortunes of Mociño.

That Menzies was highly honored is evidenced by his election to the Linnaean Society in 1790, of which he later became president. He died on February 15, 1842, an outstanding pioneer of northwest natural history. An island in the Columbia River, *Arbutus menziesii*, *Spiraea menziesii*, and the ericaceous genus *Menziesia* preserve his name for posterity.

#### ALEXANDER VON HUMBOLDT

Alexander von Humboldt, the great German scientist, journeyed in Mexico from March 23, 1803, until March 7, 1804. It is not necessary for us to consider the life and works of this famous scientist, as they are too well known. Born in Berlin on September 14, 1769, he was occupied throughout his life with investigations of physical and natural phenomena. He died May 6, 1859.

The sojourn in Mexico followed upon his journey to South America. While in Mexico, Humboldt made his usual thorough studies of the region, embracing astronomy, geology, mineralogy, botany, and zoology. In a letter he writes,

"We have already despatched to Europe some ten or twelve consignments of newly gathered seeds; one parcel went to the Botanic Gardens at Madrid, among which, as I learn from the 'Annales de Historia Natural,' Cavanilles has already discovered some new species; a second parcel was enclosed to the Jardin des Plantes at Paris; and a third went by way of Trinidad to Sir Joseph Banks in London."<sup>61</sup>

From his specimens and notes a vast amount was added to the knowledge of the flora and fauna of tropical America. The botanist Bonpland<sup>62</sup> accompanied him on this journey and also made extensive collections.

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\* It is interesting to note that while Menzies was apparently the first to collect the Coast Redwood (from the Santa Cruz region), this magnificent tree was first mentioned in the diary of the Jesuit missionary, Fray Juan Crespi (October, 1769), who saw it in the same area and called it the *palo colorado*.

## LEWIS AND CLARK

Little need be said here concerning the famous Lewis and Clark expedition<sup>1</sup> of 1804, since no trained naturalist was included in the party.\* However, the two leaders were not lacking in zeal for the natural sciences, although their efforts were not always properly directed, as witnessed by the day spent in pouring water down a prairie dog's hole in an effort to secure a specimen of this animal. The party did, however, collect specimens of various plants and animals along the route, including Clark's crow, Lewis' woodpecker, and the Louisiana tanager.<sup>2</sup> Among the plants collected and turned over to Pursh for description was the salmonberry, *Rubus spectabilis*, observed and described earlier by Steller. Then, too, a number of forms were described from the observations noted in the journals of the party, such as the whistling swan named by Ord.<sup>3</sup> Rafinesque, whose love of taxonomy often led him to absurd lengths, attempted to name the trees of the Fort Clatsop region, based on Lewis' descriptions. Many of these were firs and pines which, naturally, would be nearly impossible to identify without specimens, even though Lewis described them with great care. A curious fact pointed out by Coues<sup>4</sup> is that whenever Lewis described a plant in detail in his journal he rarely collected a specimen.

For the most part, then, this expedition was not an important one from the standpoint of the development of the knowledge of the flora and fauna of the region.

## GEORG HEINRICH VON LANGSDORFF

While Lewis and Clark were exploring the Oregon territory, far to the northward plans were being made by the Russian Count Rezanov at Sitka to visit California for the purpose of securing supplies for the Sitka colony. With him was the German Dr. Georg Heinrich von Langsdorff.<sup>5</sup> Both of them had originally been members of the expedition of Captain von Krusenstern which sailed from Copenhagen on September 3, 1803. Rezanov was supposed to serve as the Russian Ambassador to Japan, but having been rebuffed by that nation, he determined to visit the west coast of America in his capacity as a representative of the Russian American Company.

\* The French botanist André Michaux, who was to accompany the expedition, was recalled by his government at the request of President Jefferson, supposedly because he was a suspected secret agent of the French Government.



Consequently, he and von Langsdorff, whom he had persuaded to become his personal physician, left von Krusenstern at Petropavlovsk and proceeded to Sitka, where they arrived on August 26, 1805. They sailed from Sitka on the *Juno* March 8,\* 1806, bound for California and a fresh supply of food, and entered San Francisco Bay April 8. While on the voyage, von Langsdorff took advantage of every opportunity to observe and collect the animal and plant life. For example, he writes:

"In the afternoon a golden-winged woodpecker *Picus suaiatus*, flew on board, seeming as if it hoped to find there a place of refuge; instead of that, it found its death, since, on account of its beauty and rarity, we could not forbear sacrificing it, and preserving it as an object of natural history."<sup>13</sup>

In California they were treated very kindly by the Spanish residents, and von Langsdorff's account gives many interesting details of their visit. His observations are the more valuable, as they were the first Russians to set foot on California's shores. The collections of objects of natural history did not succeed as well as von Langsdorff wished, for he was told "that the voyage was not undertaken for the promotion of natural history." As a result, many of his specimens were lost, and finally, as he says, ". . . I became so completely discouraged that I gave up all thought of pursuing further labor in the interest of natural history. . . ." Despite this fact, von Langsdorff did secure some specimens which were deposited at the St. Petersburg museum.<sup>14</sup> The expedition left San Francisco in late May and returned to Sitka where von Langsdorff left Rezánov and proceeded to Moscow after wintering at Kamchatka.

Von Langsdorff<sup>15</sup> was born in 1774 in Rhine Hesse and died on June 29, 1852, at Freiburg, Breisgau, Baden. His education was received at Buchsweiler, Alsatia, and at the Gymnasium at Idstern, Hesse-Nassau. He obtained the degree of doctor of medicine and surgery at Göttingen in 1797. Following this, he went with Prince Christian of Waldeck to Portugal, where he served as a physician, first with Prince Christian and later with the English troops resident in Portugal. After the campaign of 1801 against the Spanish, he left the English army and subsequently secured the forementioned post as naturalist to the von Krusenstern expedition. In the next few

\* Gregorian calendar. Langsdorff used the Julian, as was the Russian custom. This date would be February 25 by that reckoning.

years after the expedition he became interested in the promotion of colonies in Brazil, where he remained for some time. The last years of his life were spent in Germany. Von Langsdorff was evidently a well-known naturalist of the period; he was a corresponding member of the Imperial Academy of Sciences at St. Petersburg and was a friend of the great Geoffroy Saint-Hilaire and the zoologist Tilesius.

As was mentioned above, N. P. Rezánov, in the company of von Langsdorff, sailed from Sitka to San Francisco in the year 1806. It was Rezánov who conceived the idea of establishing a colony<sup>5</sup> in California for the purpose of trading with the Spanish and also to secure a permanent source of food for the Russian colonies in Alaska. Negotiations with the Spanish were completed, and six years later, in 1812, Bodega Bay was occupied by the Russians. They selected a site eighteen miles north of the bay and there began the construction of Fort Ross on March 15, 1812. As the sea otter industry soon failed and as the settlers were not skilled agriculturalists, the colony did not prosper. The Russian American Company, always hopeful of placing the venture on a paying basis, maintained the fort until 1841, when they sold it and the adjacent lands and livestock to the famous John A. Sutter of New Helvetia.

Among the most famous of Russian-German scientists to visit the settlement were von Chamisso and Eschscholtz, on the expedition commanded by Otto von Kotzebue.

#### ADELBERT VON CHAMISSO

"In the year of Our Lord One Thousand Eight Hundred and Fifteen, Count Romanzoff,\* Chancellor of the Empire, etc., the magnanimous patron of all the arts and sciences in Russia, equipped, at his own expense, an exploration ship, with the principal purpose of exploring Bering's Straits and the American coast east of it."

Thus wrote Adelbert von Chamisso in his preface to the *Taxonomy of the Plants, Observed by Romanzoff's Expedition of Discovery*.<sup>54</sup>

Following the circumnavigation of the globe by Naval Captain von Krusenstern (1803-1804), interest in the Russian Americas, incipient in the middle of the eighteenth century, was on the increase. Romanzoff was an actively interested patron of this enterprise. Retiring in 1814, he prepared to devote his leisure time to his country's eastern outposts. Among the personnel of the von Krusen-

\* Also spelled Rumjanzoff, Rumanzow.

stern expedition was a young lieutenant in the Imperial Russian Navy named Otto von Kotzebue. Upon the recommendation of von Krusenstern, Romanzoff placed him in command of a two-masted brig given the name of *Rurik*. Avowed purpose of the expedition was the ever-popular search for a passage from the North Pacific to the Atlantic; actually the primary purpose seems to have been to ascertain the strength of the ever-weakening hand of Spain in Alta California.

Besides the crew, numbering about twenty-five, was a scientific staff consisting of the usual ship's surgeon, a naturalist, and an artist. Von Chamisso filled the position of naturalist. The surgeon was one Frederick Eschscholtz, M.D., of whom von Chamisso writes "... a highly successful scientist. From the initial handshake on, he and I formed an intimate friendship whose sky will never be clouded. We shared all our studies, troubles, and pleasures." Louis Choris was the artist.

Let us see how it was that this son of a French emigrant became the academical associate of von Humboldt, von Buch, Ehrenberg, and Johannes Müller. Louis Charles Adelaide de Chamisso—as he was christened—was born into nobility in the château of Boncourt in Champagne early in the year 1781. Driven from their native country by the Revolution, the Chamissos finally found refuge in Berlin. Under Napoleon the family returned to France, but Adelbert, who, after serving in the court of Frederick William was given a lieutenancy in the Prussian army, remained in Germany. He became wearied with army life and took up the study of languages in his leisure time. Following a visit to his family, he became depressed in the discovery that he was a "man without a country" and turned more fervently to his studies.

After the Napoleonic conquest of Prussia, throughout which he was a prisoner and so was spared the ordeal of meeting his countrymen in battle, von Chamisso made the acquaintance of Madame de Staël and spent the year 1811–12 with her and her son in Switzerland. It was here he first became seriously interested in botany and received instruction in this science from August de Staël. The generic name *Staëlia* commemorates this relationship. After returning to Berlin he continued his studies, paying particular attention to the methods and theories of botany.

In his thirty-first year he matriculated at the newly established

University of Berlin, studying anatomy under the elder Knappe. He also worked at the Zoological Museum under Lichtenstein, aiding in the classification of animals. He undoubtedly attended Rudolphi's lectures on comparative anatomy and physiology.\*

During the War of Liberation, by which his peculiar national position was again brought home to him, he lived in seclusion at the home of friends. During this period he continued his botanical studies and also work on his romantic narrative, *Peter Schlemihl*, for which he is well known in the world of literature.

In 1815 quite by accident a friend mentioned the impending voyage of Romanzoff. Von Chamisso impulsively expressed the desire, long cherished, to travel in foreign lands. The friend, Julius Eduard Hitzig,\*\* was acquainted with the father of the proposed captain, von Kotzebue, and through him von Chamisso's application was made to von Krusenstern. By a quirk of fate the original naturalist, Professor Friedrich von Ledebour, fell ill, and von Chamisso received his appointment.

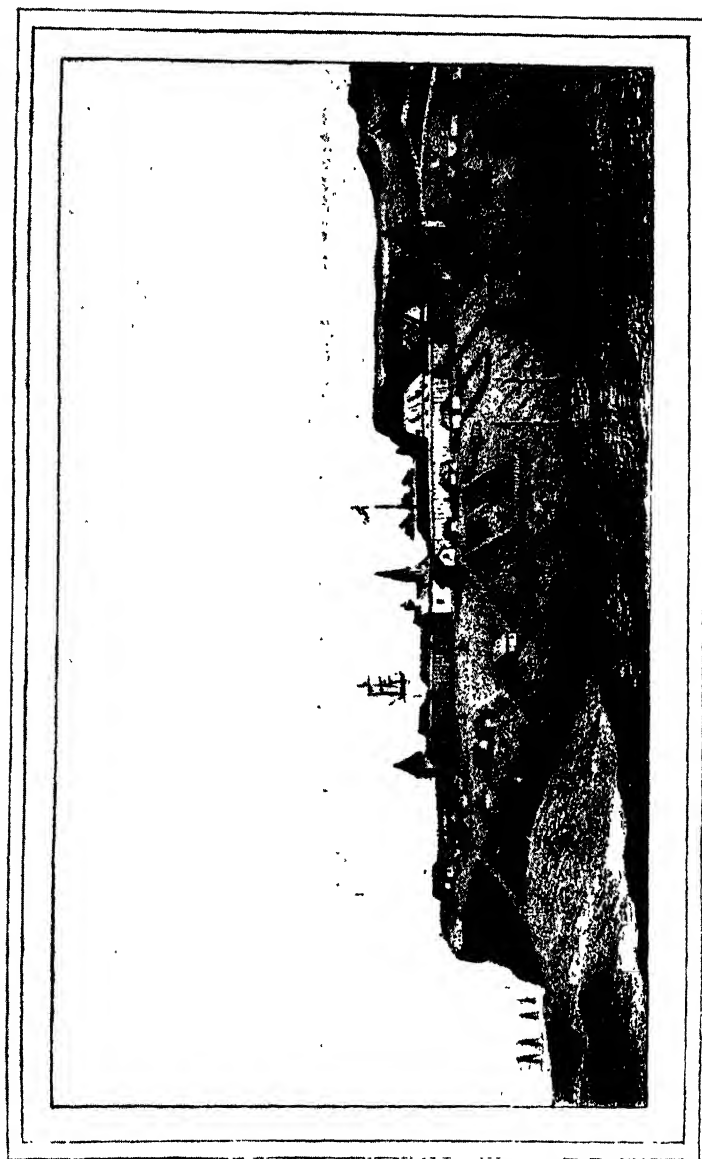
Late in July the *Rurik* weighed anchor from Kronstadt and put to sea, and ten days later (August 9) von Chamisso boarded her at Copenhagen. In the summer of 1816 the *Rurik* was cautiously feeling its way along the Alaskan coast. Here it was decided to give up the alleged object of the voyage; Kotzebue Sound, Eschscholtz Bay, and the Chamisso Islands are reminders of this abortive search for a northwest passage.

At four o'clock in the afternoon of October 2, 1816, the *Rurik* entered the harbor of San Francisco, where she remained a month lacking one day. During this period von Chamisso was busy from dawn till dusk taking part in numerous activities and making extensive notes on the country and its inhabitants. As a botanist, his reaction was somewhat mixed:

"The Flora of this country is poor, and is not adorned by one of those species of plants which are produced by a warmer sun. It however offers much novelty to the botanist. Well known North American species are found mixed with others belonging to the country; and most of the kinds are yet undescribed. Only Archibald Menzies and Langsdorff have made collections here; and the fruits of their industry are not yet made known to the world."<sup>54</sup>

\* It was to Karl Asmund Rudolphi (1771-1832), German scientist at the University of Berlin, that von Chamisso took the skull of a native California bear for identification.

\*\* Later von Chamisso's biographer.



*From the collection of the British Museum*

*Vue de l'établissement russe de la Bodega,  
à la Côte de la Nouvelle Zélande, en 1811.*

\*From a drawing in Dubaut-Cilly's *Voyage Autour du Monde*, Paris, 1835. The term "Bodega" is an obvious error for "Fort Ross.")

But botany was not his only interest; he notes "an uncommon number and variety of birds," and exhibits particular interest in the native bear, which he says "is uncommonly large, powerful, savage and tenacious of life. He attacks men and animals . . . and collects in countless troupes, around the dead whales that are cast on the beach."<sup>4</sup>

Von Chamisso paid particular attention to the aborigines. Says he, "Every fragment of the history of man is important. We must leave it to our successors, as our predecessors have done to us. . . ."<sup>5</sup> Here in California, as elsewhere in his travels, he made a careful study of the languages and noted the extraordinary number of tongues found in this small area. This phenomenon he astutely contrasts with the singular uniformity of language among the highly dispersed South Sea Islands.

Early in the morning of November 1, the *Rurik* weighed anchor and sailed for the Sandwich Islands. Unlike Darwin, whose voyage in the *Beagle* has been compared to that of the *Rurik*, von Chamisso did not sail under a sympathetic officer, for while Captain FitzRoy did everything to aid the young naturalist Darwin, Captain von Kotzebue of the *Rurik* gave von Chamisso no help whatsoever, and refused on most occasions to stow his collections on board. With this in mind it is remarkable that von Chamisso was able to bring home the material he did, along with his detailed observations which contributed to the fields of botany, zoology,\* natural history, geographical distribution of plants and animals, geology, geographical physics, anthropology, and folklore.

On the third of August, 1818, the *Rurik* dropped anchor in the Neva; the expedition was broken up, and von Chamisso was told he might have what he had collected. Refusing an offer to remain in Russia, he left for Berlin, having touched four continents and, strangely enough, covered Schlemihl's journey! In London von Chamisso met Cuvier\*\* and Sir Joseph Banks. Soon after his arrival in Berlin he received a position as assistant in the Botanical Garden and later in the Herbarium, where he remained until his retirement shortly before his death in 1838. The publication of the botanical results of the *Rurik's* voyage brought him the nomination by Alexan-

\* Von Chamisso is perhaps best known for his discovery of the alternation of generations in the *Salpae*.

\*\* Cuvier, on the evidence of a drawing, referred a tusk found by von Chamisso on Kotzebue Sound to a mammoth.



*Eschscholtzia californica* Cham., California Poppy

Reproduced from the colored plate in *Horae Physicae Berolinensis*, etc. *Ex Plantis Expeditione Romanzoffiana detectis genera tria nova offert* Adalbertus de Chamisso

der von Humboldt for membership in the Royal Prussian Academy of Sciences, to which he was elected in 1835.

In summing up the work of von Chamisso we turn to the words of DuBois-Reymond.

"Considering his [von Chamisso's] activity as a whole, it must be conceded that his strength did not lie in the direction of strict theoretical analysis. This is not to be wondered at if we consider the condition of theoretical science [Schelling's school was at its height] in Germany at the time, when it was just beginning to recover from its encircling entanglement with philosophy. But the characteristic and really remarkable feature of Chamisso's scientific activity is his power of embracing the whole world of phenomena with the same love, freshness, and elasticity—from the stone that rung under his geological hammer; the hay, as he modestly named his dried favorites; the sea-worm, which revealed to him one of its most wonderful mysteries; to that noblest production of Nature, as man represents himself to objective research, whether considered as a single being related to the animals, as a tool-making, fire-using, social creature, or, in his highest expression of speech. With sound, lively sense, with always ready energy, Chamisso stands before the things of Nature, exercises unreservedly every kind of observation, and forms his conceptions without prepossession and with strict limitation to the actually known. He was thus, although his monographs may have been overtaken or his general views have fallen behind those of the present day, a complete naturalist in the best sense of the word, and that at a time when such men had to be looked for through Germany as with a candle."<sup>10</sup>

#### JOHANN FRIEDRICH ESCHSCHOLTZ

Johann Friedrich Eschscholtz was one of the leading zoologists of his day. As was mentioned, he served as ship's surgeon on the *Rurik* and was a close friend of von Chamisso. Though conditions were unfavorable (the season was far advanced), Eschscholtz devoted much effort in making a representative collection; he turned his plants over to von Chamisso, who proceeded to commemorate their friendship by christening the California poppy *Eschscholtzia californica*. Because of the unusual dryness of the season, Eschscholtz' zoological collections were not extensive.

When Captain von Kotzebue returned to the California coast eight years later, Eschscholtz accompanied him as naturalist; Ernst Hoffman (1801–70), who was on board, also collected on the west coast. The vessel, the *Predpriactë*, was in San Francisco Bay on September 27, 1824, and from here a three-day visit was made to the mission of



Santa Clara, where Eschscholtz made part of his beetle collection. On the third of October, 1824, he and Hoffman made an excursion to Fort Ross, Bodega Bay, and the surrounding area; other trips were made to the San Joaquin and Sacramento rivers. After nearly two months of extensive exploration, they left San Francisco on November 25, 1824. Eschscholtz' collections from this trip around the world included a grand total of 2400 animals, of which twenty-eight were mammals, 165 birds, thirty-three amphibia, ninety fish, 1400 insects, and some 681 other invertebrates.

Born in Dorpat November 1, 1793,\* Eschscholtz early showed an inclination for natural science; at the age of eight, without the slightest suggestion from others, he began a collection of beetles and plants. His early education was obtained from the public schools of Dorpat, and he studied medicine from 1812 to 1815 at the University of Dorpat. The essentials of botany he gained from Professor Karl Friedrich von Ledebour, who later became his brother-in-law; finally his interests settled on zoology. Following his trip in 1815 on the *Rurik*, Eschscholtz was appointed professor extraordinary and curator of the zoological museum at Dorpat; in 1822 he was named professor ordinary and director of the museum.

The results of his second journey with von Kotzebue were published in his *Zoologischer Atlas*.\* This atlas was published in a series of small volumes from 1829 to 1833. Unfortunately, Eschscholtz died on the seventh of May, 1831, before the completion of the atlas. The work was finished from his notes and further observations by Dr. Martin Heinrich Rathke, a colleague at Dorpat. In addition to the atlas, Eschscholtz published many other valuable contributions to zoological literature.\*\*

Of him Rathke wrote,

"Ein Mann nun, der mit gesundem Sinne, mit schonen Gaben des Geistes, und mit einem wissenschaftlichen Streben, das nur dem höchsten Ziele galt und keine Anstrengung und Opfer scheute, ausgerüstet war, ein Mann, der seine Fähigkeiten zu üben Gelegenheit gehabt hatte, wie nicht leicht Einer. . . ."

\* From the introduction by M. H. Rathke to vol. 5 of Eschscholtz, *Zoologischer Atlas*.<sup>34</sup>

\*\* For a list of these see p. v of Rathke's introduction to vol. 5 of Eschscholtz, *Zoologischer Atlas*.

## OTHER RUSSIAN NATURALISTS

In the last years of the Russian occupation, a number of other Russian naturalists and collectors visited the coast and Fort Ross. As F. O. Essig writes:

"Among these were Ferdinand P. Wrangell, Governor of Russian America; Dr. F. Fischer, a physician of the Russian American Company and a collector of insects in Alaska and at Ross; Dr. Edward L. Blaschke, also a physician of the Company and an ardent collector of beetles in Sitka and California; George Tschernikh, an agriculturist and overseer of the Tschernikh Ranch . . . a most industrious and successful collector of beetles in Alaska and in California, and I. G. Vosnesensky, naturalist and curator of the Zoological Museum of the Academy of Natural Sciences, St. Petersburg.\* The last named was the only trained entomologist, being sent out by the museum to collect insects in California. He collected extensively over the territory occupied by the Russians from Bodega Bay to Ross and also around San Francisco, at New Helvetia [Sacramento] and the area between Ross and the upper San Francisco Bay region. With Tschernikh, on June 12, 1841, he was the first to climb Mount St. Helena, which he named for the Empress of Russia."<sup>18</sup>

Following the sale of Fort Ross and the withdrawal of the Russians, the Czar's Government took no further interest in California. Alaska alone remained under Russia and no further scientific expeditions from that country visited the coast after 1842.

## WILLIAM BULLOCK

In 1822-1823 an Englishman, William Bullock, a collector and proprietor of the London Museum (a private museum), traveled in Mexico and made collections of plants and birds of the region. Bullock published an interesting account of his journey and gives us a view of Mexico at that time.<sup>19</sup> He visited the Botanic Gardens, where he secured seeds of Mexican plants which he took to England with him. He mentions that the curator of the Garden was an Italian, and the director was Professor Vincente Cervantes, both of whose salaries were about to be discontinued because of the lack of state funds. Everywhere he noted the decadent state of the arts and sciences in Mexico.

Bullock collected many birds of the country and one chapter of his narrative is devoted to the hummingbirds, which were rarities

\* Plants collected by Vosnesensky have recently been returned to California for identification, after the lapse of nearly a hundred years.<sup>15</sup>

to him. Swainson in 1827 described some of the birds Bullock collected, including the California woodpecker, black phoebe, Bullock's oriole, black-headed grosbeak, violet-green swallow, and dipper.\* In 1827 he again was in Mexico, returning by way of the United States. An account of this journey was published as "Sketch of a Journey through the Western States of North America."\*

The dates of his birth and death are not certain, and little is known of his life other than the material found in his two books. He was a member of a number of learned societies, including the Linnean, Horticultural, Geological, and Wernerian.

#### BEECHY'S VOYAGE

"As we have appointed Mr. Tradescant Lay as naturalist on the voyage . . . it is expected that your visits . . . will afford the means of collecting rare and curious specimens in the several departments . . . of science. . . . two specimens, *at least*, of each article are to be reserved for the public museums. . . . You will pay every attention in your power to the preservation of the various specimens of natural history . . . and if, on your arrival at any place in the course of your voyage, you should meet with a safe conveyance to England, you are to avail yourself of it to send home any dispatches you may have, accompanied by journals, charts, drawings, etc., and such specimens of natural history as may have been collected. . . . In the event of England becoming involved in hostilities . . . during your absence . . . you are not on any account to commit any hostile act . . . the vessel you command being sent out only for the purpose of discovery and science. . . ."

Thus read the instructions of the Lords Commissioners of the Admiralty to the Commander of H.M.S. *Blossom*, ready at Spithead to weigh anchor for the Pacific on May 19, 1825.

Among the officers listed were Alexander Collie, Surgeon, and George Tradescant Lay, Naturalist.\*\* The nature of the voyage prevented the retention of the ship at one place for any considerable period, and as a result the collections, like those of many of the earlier and later expeditions, did not truly represent the fauna and flora of a region but rather served "to bring together a variety of rare species from distant localities, some of which have been but seldom, if ever, visited by any collector."

It is unfortunate that very little can be learned of either Collie

\* The writers were unable to examine this work.

\*\* Lieutenant Belcher aided Collie and Lay, and himself made a collection of minerals which he presented to the Geological Society of London.

or Lay, but a glance at the reports on the zoology and botany of Captain Becchey's voyage will show that they were exceedingly observant and careful collectors. Collie was obviously an able man, astute in his observations and careful in his dissections, checking any peculiarity on a second specimen. Lay is responsible for some half dozen miscellaneous papers appearing between 1829 and 1842. Their material is extensively reported on by Richardson, Vigors, Owen, Hooker, and others.<sup>73</sup> The notes of Collie and Lay were carefully written and illustrated—so well (it is perhaps to be regretted) that, as was the custom at the time, many new species were set up from descriptions alone. Methods of preservation were so inadequate that much of the material was too poor to describe accurately, and this led to further errors.

San Francisco in November, 1826, and Monterey Bay on January 1, 1827, received the *Blossom*, and the California jay, pygmy nut-hatch, California towhee, and redshafted flicker represent new species collected from these regions.<sup>74</sup> As usual, names of the officers were commemorated in bird, beast, and fish. The plants collected by Lay and Collie were described by Sir William Jackson Hooker and C. A. Walker-Arnott, who published in London, in 1841,<sup>75</sup> a quarto volume with ninety-four plates; many of these plants were collected in California.

#### PAOLO EMILIO BOTTA

On the twenty-sixth of January, 1827, San Francisco was visited by the French vessel *Héros* under the command of Auguste Bernard du Hautcilly (or Dubaut-Cilly). Aboard the vessel as ship's doctor was Paolo Emilio Botta, whom we are interested in as a collector, particularly of birds. The expedition spent nearly two years in California; some two months of the time, however, they were in Peru. While on the coast they visited, in addition to San Francisco, the Russian colony and Bodega, Los Angeles, San Diego, and other points. They finally sailed from California on July 27, 1828. The account written by du Hautcilly<sup>76</sup> is chiefly of interest from the historical viewpoint, but it does contain some references to Dr. Botta's collecting. Botta himself wrote some observations dealing

\* This volume was not available for our use. Instead we used Carlo Botta's translation,<sup>76</sup> and an English translation.<sup>77</sup> This contains only the portion dealing with California and does not include Botta's observations.

largely with the natives of California and Hawaii\* but with some notes on the animal life. Du Hautcilly must have collected also to some extent, for he says,

"As for the collection I was engaged in with Dr. Botta, our quests were not less fruitful; on the seashore a swarm of beautiful shore-birds; in the woods and on the hills, several fine species of hawk and other birds of prey; in the thicket magpies, blackbirds, sparrows, and several frugivorous birds all different from ours; finally in the heath, a pretty species of humming-bird, perhaps the smallest existing, with a head and throat of glowing fire."<sup>17</sup>

Botta is chiefly of interest because it was from a specimen collected by him that Lesson described the California road runner.<sup>18</sup> It is surely to this striking bird that Botta referred when he wrote:

"The bird called *charia* runs very swiftly, jumping occasionally and beating its wings, which we might call flying. It is so poorly qualified to fly, however, that when it advances into the open it is possible, either on foot or on horseback, to catch it alive. It is known for destroying the rattlesnake and other reptiles."<sup>19</sup>

Concerning Botta we know that he was the son of Carlo Botta, the Italian historian, who later became a French citizen. Paolo Emilio was born in 1805 and so was only twenty-two when he accompanied du Hautcilly on his voyage. Later he was appointed French consul to Alexandria, Mousoul, and Tripoli. In 1842, while still a consul, he began the search of the ruins of Nineveh resulting in the discoveries upon which his fame rests. The basis of the Assyrian collection in the Louvre is formed from his work. His publications in the field of archeology are noteworthy. He did not appear to occupy himself with natural history further than already noted. His death occurred in April of 1870.

#### DAVID DOUGLAS

No traveler in the Pacific northwest can leave this region of mighty mountains, somber forests, and turbulent streams without being awed by the grandeur of the virgin stands of the Douglas fir,

\* Botta's account is bound with the Duhaut-Cally volume and entitled "Osservazioni su gli abitanti delle Isole Sandwich e della California"

\*\* A free translation of the original "L'uccello chiamato *charia* corre assai veloce, salta qualche volta battendo le ali piuttosto, che di si possa che voli; Così poco abile è al volare, che quando s'inbatte in luoghi aperti si può prendere vivo, seguedolo a piedi a cavallo. Ha fama di distruggere i serpenti a sonaglio ed altri rettili."<sup>20</sup>

a fitting memorial to that great botanical explorer, David Douglas. The story of his journeys in this region forms one of the most fascinating chapters in the natural history of the west.

In far-off London, members of the London Horticultural Society,



ever desirous of obtaining undescribed species from the little-known coast of western America, determined to send a collector to this region to secure seeds and specimens of its flora. They chose as their agent a Scotch gardener and botanist, David Douglas, who had successfully undertaken a similar commission for them to the eastern portion of the United States in 1823.

Douglas,<sup>20</sup> the second son of John Douglas, a stonemason, was born in 1798 at Scone, Perthshire. After his early education at the Scone

and Kinnoul schools he was apprenticed in the gardens of the Earl of Mansfield. In 1817 he became the undergardener to Sir Robert Preston at Valleyfield. Later he went to the Botanical Gardens at Glasgow, where he attracted the attention of the famous botanist, W. J. Hooker, whom he often accompanied on collecting trips into the highlands. Through the good offices of Hooker he received his first commission from the Society at the age of twenty-five.

Embarking on the Hudson's Bay Company's brig *William & Ann*, Douglas set sail July 25, 1824, for the "entrance to the River Columbia." Aboard the vessel he found a very agreeable companion in the person of Dr. John Scouler, whom we shall discuss later. The voyage passed pleasantly enough for such a nature lover as Douglas. Every page of his journal<sup>20</sup> is filled with observations on the sea birds, marine plants and animals, and notes concerning the flora of the various islands visited en route. We find him something of a herpetologist as well, for he remarks in reference to a loss of specimens due to rain, "Nothing did I regret so much as a new species of *Lacerta*, 20 to 30 inches long, of a dark orange colour, a rough warty skin, and which made good soup."<sup>21</sup>

After a voyage of eight months and fourteen days, on April 7th the *William & Ann* entered the mouth of the Columbia and anchored in Baker's Bay. We can well imagine the great joy and excitement that must have stirred Douglas on viewing this promising land. Because of heavy rain the party did not put ashore until April 9th. Douglas describes the landing:<sup>22</sup>

"On stepping on the shore, *Gaultheria Shallon*\* was the first plant I took in my hands. So pleased was I that I could scarcely see anything but it. Mr. Menzies correctly observes that it grows under thick pine-forests in great luxuriance and would make a valuable addition to our gardens . . . *Rubus spectabilis*\*\* was also abundant; both these delightful plants in blossom."

From 1824 until 1827 he was busily engaged in exploring the region drained by the Columbia River. His journeys took him past The Dalles, to the mouth of the Snake or Lewis and Clark River and to old Fort Walla Walla. From there he made side excursions into the neighboring Blue Mountains. He journeyed on up the Colum-

\* Called *salal* by the natives, which is the common name in use today. Menzies first discovered it.

\*\* The ubiquitous salmonberry mentioned by Steller and Lewis and Clark.

bia to the Spokane River, botanizing as he went. Passing the famous Grand Coulee, he was greatly impressed by this wonder of nature. In between the various journeys he made in the region, Fort Vancouver served as his base, where the Hudson's Bay Company's Chief Factor, Dr. John McLoughlin, offered every kindness in his power to aid Douglas in his work. Because of his assistance to Douglas and many other scientists, pioneers and settlers, English and otherwise, McLoughlin is deserving of the highest praise.<sup>18</sup> In many cases his services to American settlers were in direct opposition to the policies of his company in its attempt to maintain the Oregon country for Great Britain, but the call of humanity was the first to be answered by this kind-hearted man.

Danger was a constant companion on all of these trips from the base, for the Indians were notoriously fickle and treacherous. While searching for the sugar-pine (*Pinus lambertiana*), which he had first learned about through some seeds and scales carried by an Indian, Douglas made a long journey into southern Oregon, into the rugged country of the Umpqua River. Here he found stands of this beautiful tree, but in attempting to shoot down some cones from them he attracted a band of hostile Indians, who, as he says,

"... were all painted with red earth, armed with bows, arrows, spears of bone, and flint knives, and seemed to me anything but friendly. . . . To save myself I could not do by flight, and without any hesitation I went backwards six paces and cocked my gun, and then pulled from my belt one of my pistols, which I held in my left hand. I was determined to fight for my life."<sup>19</sup>

The dangerous moment passed and Douglas was able to get specimens of the pine. Having no idea when the Indians might return, his diary entry that night states:

"How irksome a night is to such a one as me under my circumstances! Cannot speak a word to my guide, not a book to read, constantly in expectation of an attack, and the position I am now in is lying on the grass with my gun beside me, writing by the light of my Columbian candle—namely, a piece of wood containing rosin."<sup>20</sup>

Such then were the hazards of collecting in those early days, and it must have taken men with boundless love of nature to risk their lives for the sake of a new plant or animal.

In the spring of 1827, Douglas left for England by the overland



route, crossing the Canadian Rockies and embarking on a Hudson Bay vessel at York Factory. He arrived in England with some 210 species of plants in addition to the many he had sent before.

The members of the Society were so pleased with the results of the expedition that they asked him to return. On October 18, 1829, he sailed again for the west coast. This time his attention was turned to California, where he landed at San Francisco in 1831. Being unable to get a ship for the Columbia, he remained and collected in the region around Monterey until August, 1832, when he sailed for the Sandwich Islands. From there he sent his California collections on to the Society. Later he returned to the Columbia River, but on the way he learned of the resignation of his personal friend, Joseph Sabine, from the secretaryship of the Society. Through some misunderstanding, Douglas resigned also, but he continued collecting in the region for over a year. Less is known about his activities during this period. From Oregon he returned to the Sandwich Islands, arriving on January 2, 1834. On the seventh he climbed Mauna Loa, about which he wrote his brother. This was his last letter, for on July 12, 1834, he was killed, supposedly by falling into a wild cattle pit, where he was gored to death by a bullock. The circumstances surrounding his death were uncertain and there was some suspicion that he had been murdered by the natives, while others reported him murdered by an escaped convict from Botany Bay.<sup>26</sup>

Concerning Douglas' work too high an evaluation can hardly be made. While most of his contributions were in the realm of botany, including the introduction of hundreds of plants to the gardens of Europe, and the discovery of many new species of pines, firs, spruces and *Ribes*, he also made valuable contributions to zoology. His journal contains references to many birds, mammals and other animals. Some of his observations were published, such as "Observations on the *Vultur californianus* of Shaw"<sup>27</sup> and "Observations on two undescribed species of North American Mammalia, *Cervus leucurus* et *Ovis californianus*."<sup>28</sup> In all, his publications amounted to some fourteen papers, chiefly botanical. Douglas, no mere collector, was a skilled natural scientist in his own right. Of his character and personality, what more need we say than he courageously faced adversity for the science he loved, and died in pursuit of knowledge?

It was not until twenty-two years after his death that a monument was erected over Douglas' grave by a Frenchman, Julius L. Brenc-

ley. In Latin is his inscription and title "victima scientiae"—it is unfortunate that it does not contain the Indian name he loved so well—"the man of grass."

#### JOHN SCOUTER

As was mentioned, Douglas' companion on the first voyage to the west was John Scouler, physician on the *William & Ann*. That Douglas was so attracted to him was due, no doubt, to Scouler's interest and skill in natural history. Scouler was born in Glasgow on December 31, 1804. His early education was received at Kilburchin and the University of Glasgow, where he completed the medical course. His interests were primarily in natural history; following his work at Glasgow he studied in Paris at the Jardin des Plantes. Then, like so many other adventuresome physicians of his time, he shipped with the Hudson's Bay Company as a surgeon.

We find that, like Douglas, Scouler kept a diary of his journey,<sup>78, 79</sup> and it is interesting to compare the two. Scouler, while an excellent botanist, was also interested in zoology, particularly anatomy. On the voyage he noted that the range of *Diomedea exulans* was greater than Cuvier had stated, and that this was the first error he had ever found in Cuvier's work. The anatomy of the bird was carefully studied also.

On another occasion we find him dissecting a water snake some thirty miles from Fort George, about which he said, "On dissecting him, after preparing the skin, I found a large bull frog, and many elytra of *Dytiscus marginalis* in his stomach."<sup>78</sup> Another time his dissecting practices disturbed the Indians, for he writes:

"I selected a few salmon and carp for dissection, but of these the Indians quickly dispossessed me, and, after extracting the hearts of all the fish they had caught, I was allowed to select as many as I pleased. Their reason for this practice was, that if their hearts were not extracted and laid aside, the other salmon would take offense, and leave the river."<sup>78</sup>

While Douglas was botanizing the upper Columbia and inland regions, Scouler visited Nootka, where he met an old Indian chief, Macuinna, who remembered Captain Cook, Vancouver and Quadra, with whom Mociño had visited Nootka.

Returning from Nootka, Scouler again met his friend Douglas and remained with him until September 20, 1825, when he left for his ship at the mouth of the Columbia. On the twenty-fifth of Octo-

ber Scouler sailed for the Hawaiian Islands and probably never saw Douglas again.

After another voyage, this time to India, Scouler practised medicine in Glasgow. In 1829 he became a professor of natural history at Andersonian University and in 1834 was appointed professor to the Royal Dublin Society in the subjects of geology, zoology, botany and mineralogy. On his retirement in 1854 he returned to Glasgow, where he died November 13, 1871.<sup>20</sup>

Besides his journeys and teaching, Scouler found time to establish the *Glasgow Medical Journal*, to serve as one of the editors of *Cheeks' Edinburgh Journal of Natural and Geographical Sciences*, and to write some twenty scientific papers of his own. Hooker named in his honor a genus of mosses, which Scouler had found, *Scouleria*.

#### KARL HEINRICH MERTENS

In 1826 still another expedition flew the imperial flag of the Romanoffs under Captain Lütke. Serving in the customary dual role of surgeon and naturalist was a young German named Karl Heinrich Mertens. Born in Bremen on the seventh of May, 1796, he early received instruction in natural history, particularly botany, from his father, later studying medicine at Göttingen. Plagued with the same desire for adventure and travel as his predecessors, Steller and von Chamisso, he set out for St. Petersburg in 1824 in the hope of obtaining a position with von Kotzebue. Failing to secure it, he turned to his profession, and until Lütke sailed in 1826 he practiced medicine in the Ukraine.

While with Lütke, he made extensive collections, including plants from the Island of Sitka. The victim of a shipboard epidemic, Mertens was stricken and died in St. Petersburg in 1832. His diary appeared later and his collections were described by Bongard, Brandt, Postel and others.

#### THOMAS COULTER

It will be recalled that Douglas was in California in 1831 and while there he met another botanist, Dr. Thomas Coulter. In a letter<sup>21</sup> to Sir William J. Hooker written in Monterey, November 23, 1831, Douglas writes:

"Since I began this letter, Dr. Coulter, from the republic of Mexico, has arrived here with the intention of taking all he can find to De Candolle at Geneva. He is a man eminently calculated to work, full of zeal, very

amiable, and I hope may do much good to science. I do assure you from my heart it is a terrible pleasure to me thus to meet a really good man, and one with whom I can talk of plants."

From Mexico, where he had been botanizing, Coulter came up to Monterey. There he met Douglas in November, 1831. He spent nearly three years on the coast<sup>m</sup> and was one of the earliest to make known the desert vegetation of the Colorado River. He also discovered Coulter's pine (*Pinus coulteri*) and preceded Douglas in the discovery in the Santa Lucia Mountains of the beautiful fir, *Abies bracteata* Don, which Douglas named *Pinus venusta*. In 1833 Coulter returned to England and was appointed curator of the herbarium of Trinity College, Dublin, a position he held until his death in 1840.

#### TOLMIE, GARDNER, WYETH, AND DEPPE

During this same period (1830-1835) while Douglas, Scouler and Coulter were on the coast, two Hudson's Bay Company medical officers were making minor collections in the northwest. One was Dr. W. F. Tolmie<sup>m</sup> (died 1886) who was the surgeon at Fort Vancouver in 1832. He was a pupil of Sir W. J. Hooker, the friend and teacher of so many of the early botanical explorers. Tolmie in 1837 was the first botanist to visit Mount Rainier. In *The Botany of Captain Beechey's Voyage* there is some material attributed to Tolmie, though he states it was collected by a friend. The other collector was Dr. Meredith Gardner (died prior to 1840) who collected a few plants about Fort Vancouver. His specimens are at Kew. The caraway, *Carum gardneri*, commemorates his name. We have been able to find nothing more concerning these men, but it is evident that their contributions were not very extensive.

In 1832-1833 Nathaniel Wyeth visited this region on his first expedition, and the plants he collected along the Flathead River were described by Thomas Nuttall, who accompanied Wyeth on the second expedition, and about whom we shall have more to say in the following pages.

Another botanical collector, Ferdinand Deppe, was in California in 1831 or 1832. According to Brewer,<sup>14</sup> he was associated with a Dr. Scheide in Mexico, but his name is seldom met with in California botany. Concerning Deppe we know little. He was from Berlin, and following his journey published a journal<sup>m</sup> on his California trip. This work was unfortunately not available for our use.

## JOHN KIRK TOWNSEND

There is much evidence that had John Kirk Townsend not been a contemporary of Audubon (he was born October 10, 1809), and had not his life been cut short by a premature death, he would have become one of the leading ornithologists of his or any other day. He has been described as an ornithologist equal to any this country has produced—a painstaking, reliable observer and a fluent and scholarly writer. But in Audubon he had a competitor exceedingly well trained who was an accomplished artist, daringly self-reliant, and who, at least in later years, had the backing of wealthy, influential friends. Townsend, on the other hand, was a modest student, completely lacking the forthright assertiveness of Audubon. He had difficulty in obtaining the then rare museum positions so that he might live at all.

Born into an intellectual Quaker family in Philadelphia, Townsend early showed an interest in ornithology and became, while yet a boy, an expert taxidermist. We may suspect that this interest was not wholly undirected, for he was not the only one in the family to exhibit a bent for natural history,\* and he attended a school wherein Thomas Say, John Cassin and Edward Drinker Cope received their early education.<sup>†</sup>

When twenty-five years old Townsend, already an ornithologist of some note, joined the expedition of Captain John B. Wyeth leaving for the Oregon country. His colleague on the journey was Thomas Nuttall, who had just published the first volume of his *Manual of Ornithology*, although he was predominately a botanist. Both men collected assiduously en route and in and about Fort Vancouver, procuring many new species. Unfortunately, Townsend devotes little space in his narrative<sup>‡</sup> to the natural history of the country and the fruits of their collections.

Again one must admire the energy of these collectors and the ingenuity they displayed in transporting their material in good condition. Like those who had gone before him, Townsend, too, had his difficulties; in one of the few references to his collections he tells of a violent storm which overtook the party on the Columbia River and during which Nuttall's plants received a wetting, but, he says,

\* His sister, Mary Townsend, was the author of *Life in the Insect World*.<sup>§</sup> This work is apparently exceedingly rare.

"My bale of birds which was equally exposed to the action of the water, escaped without any material injury."<sup>1</sup> Townsend's slight contribution to the field of herpetology is explained in his own description of the expedition's tailor, whose funeral he (perhaps with some relish) attended:

"His appetite for ardent spirits was of the most inordinate kind. During the journey across the country, I constantly carried a large two-gallon bottle of whiskey, in which I deposited various kinds of lizards and serpents. . . . I left the bottle on board the brig when I paid my first visit to the Willammet falls, and on my return found that Thomburg had decanted the liquor from the precious reptiles which I had destined for immortality, and he and one of his 'pot' companions had been 'happy' upon it for a whole day."<sup>2</sup>

Townsend carried on his collecting wherever he went and often did not limit himself strictly to his chosen field. For late one summer evening we find him robbing Indian graves to obtain skulls, knowing perfectly well that were he discovered he would be instantly shot\*—unless he had a shirt or blanket handy for a gift! Molluscs, too, and, in fact, invertebrates<sup>2</sup> of all kinds drew his interest as much as any bird.

After an absence of three and a half years Townsend returned, reaching Philadelphia on November 13, 1837.

Apparently most of Townsend's bird skins were sent back with Nuttall, who preceded him, and we find Audubon anxious to examine the specimens collected by both men. Later on when Townsend returned, financially unable to publish adequately his work, he sold additional skins to Audubon and supplied him with his notes. Thus nearly all the work of Townsend appears in the volumes of Audubon\*\* where its identity is lost. It seems regrettable that Townsend and Nuttall did not publish an ornithology under their own names in their own words; much is missed in the flowery efforts of Audubon. In the west, Townsend discovered the sage thrasher, Townsend's solitaire, the hermit warbler, Audubon's and Townsend's warbler, Townsend's bluebird, Harris' woodpecker, Vaux' swift, and many others.

According to Stone,<sup>3</sup> Townsend later planned publication of an illustrated work on the ornithology of the United States with plates

\* He had been caught once before and only escaped injury by returning the pilloined cadaver to its proper place.

\*\* Some new species were described by Bachman and Cassin.

of royal octavo size, but of that only a single part was issued,\* the venture being abandoned probably owing to the simultaneous appearance of Audubon's small edition.

A member of the Academy of Natural Sciences of Philadelphia, Townsend was twice made curator. For a period he was at the National Institute at Washington, D. C., where he mounted birds, but as he was about to receive the recognition he had so justly earned, he was discharged during a dispute between the Institute and Captain Wilkes, who was superintending the preparation of specimens from the United States Exploring Expedition.

Back in Philadelphia in 1845, Townsend was forced to take up dentistry, but seems to have had little success. Broken in health, his death occurred on February 6, 1851, due, it has been said, to the cumulative effect of arsenic which he had constantly handled throughout his life. A brother-in-law, writing in a letter, says:

"His personality was most attractive. His courtesy, kindness of heart and his brilliant conversational powers, fortified with a vivacious intellect and a fund of knowledge covering almost all subjects, made him a delightful companion and endeared him to every one who came within his influence."<sup>81</sup>

Not a martyr in any sense of the word, Townsend made sacrifices for a cause dear to his heart throughout his short life. When the insatiable hunger for priority had gripped Audubon, and this artist was showing a jealous streak foreign to his nature, Townsend, fully aware of the futility of trying to publish independently, and, we have reason to suppose, under pressure from colleagues in high places, turned over to a competitor one of the richest single collections ever made, thus relinquishing claim to a timely recognition

#### THOMAS NUTTALL

Nuttall, recalling his first view of the New World, said,<sup>82</sup>

"Scenes like these have little attraction for ordinary life. But to the Naturalist it is far otherwise: privations to him are cheaply purchased if he may but roam over the wild domain of primeval nature and behold

'Another Flora, of bolder hues  
And richer sweets, beyond our garden's pride.' "

Such a naturalist was Thomas Nuttall. And how often he was able to realize the fervent hope of the poet!

\* This is said to be among the rarest works on American ornithology.

Born of humble parentage in 1786 in the market town of Settle in the West Riding of Yorkshire, he was early apprenticed to the printers' trade. For several years he was a journeyman and often, at his own admission, did not know where his next meal was coming from or of what it might consist. When twenty-two years of age he came to America, landing at Philadelphia in the spring of 1808. He had apparently devoted himself to study from an early age, for upon his arrival he was described as being exceptionally well informed.

He early came under the influence of Professor Benjamin S. Barton, who became his fast friend and patron. Nuttall became an assiduous collector and his trips became more frequent and of longer duration. He attained some early training in his field by accompanying one John Bradbury, a Scotch naturalist, on a trip to the headwaters of the Missouri. Here he had his first introduction to the perils of wilderness life. Fatigued and half starved, pursued and robbed by Indians, he once laid himself down to die, but was rescued by friendly Indians; yet he succeeded in bringing back an extensive collection of seeds, plants and minerals.

The next eight years were spent in Philadelphia, during which time he prepared the work upon which his reputation as a botanist principally rests, namely: *Genera of North American Plants*. Of it Professor Torrey says in the preface to his *Flora*, it "... contributed more than any other work to the advance of the accurate knowledge of the plants of this country." It is interesting to note that Nuttall turned his early trade to good use by setting up the greater part of the type himself.

Already a member of the Linnaean Society, Nuttall was elected, in 1817, a member of the American Philosophical Society, and a corresponding member of the Academy of Natural Sciences in Philadelphia. These honors placed him in contact with the eminent learned men of the country.

The years between 1818 and 1820 he spent in the Arkansas country; in sixteen months he covered 5000 miles of hostile Indian country, which for the most part had never before been visited by scientific explorers. Again he suffered from illness and mistreatment from the Indians, but eventually he made his way home and spent two years working over his treasured collections.

In 1822 he was called to Harvard, where he soon earned the well-deserved description of a fussy recluse. To avoid meeting fellow





THOMAS NUTTALL.

boarders at the house in which he lived, he cut a window to the floor to provide a private entrance and made a trap-door in the ceiling of his study to reach his bedroom above. Besides his botany, he spent much time studying mineralogy, perhaps his favorite science, and ornithology, and, claiming he was "vegetating like his plants," he produced in 1832 a two-volume work entitled *Manual of the Ornithology of the United States and Canada*. A year later he went to Philadelphia to work over the collections brought back from Wyeth's first trip to the Pacific,<sup>22</sup> and in 1834 the intrepid collector, not able to get an extended leave, resigned from Harvard and joined the explorer on his second expedition.

During the slow, tortuous journey to the Pacific, his young naturalist friend and companion, John Kirk Townsend, sent out by the Philosophical Society and the Academy of Natural Sciences, describes him as a tireless and fearless collector, constantly annoying guards deployed about the evening camp by wandering to some wooded hillock and risking his scalp for bird or flower. On one occasion a band of hostile Indians approached camp and the alarm was given, but Nuttall was not in sight. An anxious friend finally located him studiously examining a plant recently collected. The rescuer apprised him of the danger and asked if his gun was in order. Alas! it had been recently used to uproot specimens and was thoroughly spiked with mud and gravel.

The endurance and capacity for work displayed by this frail man were amazing. Following a terrific storm on the Columbia, nearly costing the lives of both naturalists, Townsend writes:

"Mr. N's large and beautiful collection of new and rare plants was considerably injured by the wetting it received; he has been constantly engaged since we landed yesterday, in opening and drying them. In this task he exhibits a degree of patience and perseverance which is truly astonishing; sitting on the ground, and steaming over the enormous fire, for hours together, drying the papers, and re-arranging the whole collection, specimen by specimen, while the great drops of perspiration roll unheeded from his brow."

And again,

"... I have had constantly to admire the ardor and perfect indefatigability with which he has devoted himself to the grand object of his tour. No difficulty, no danger, no fatigue has ever daunted him, and he finds his rich reward in the addition of nearly a thousand new species of American plants. . . ."

In 1835 Nuttall visited the Sandwich Islands, but returned to continue his collections in California. Late in the year he took ship for home; en route he was much piqued with the captain's indifference to the cause of science by his persistent refusal, while rounding the Horn in a gale, to have him rowed ashore amid the icebergs so that he might collect!

Returning to Philadelphia with his treasures, Nuttall worked for several years at the Academy of Natural Sciences with his friend Dr. Pickering, publishing two memoirs in the *Transactions of the American Philosophical Society* (1840).\*

Nuttall was described by one who knew him as a remarkable looking man with large bald head, wide brow and gray eyes; his figure was short and stooped, his fair complexion pale from constant work. In 1841 he returned to England, where he remained for the last seventeen years of his life—but for one return trip to America, when he studied the collections brought back from the Rockies and Upper California by Dr. William Gambel.

Immediately after his death on September 10, 1859, Elias Durand<sup>22</sup> said of him, "No other explorer of botany of North America has personally made more discoveries; no writer on American plants, except perhaps Professor Asa Gray, has described more new genera and species."

Thomas Nuttall was one of those rare beings so devoted to the cause of science that even the smallest personal comforts were discarded to further its purpose. Through this love of study he raised himself from a penniless orphan to a highly respected man of science.

#### RICHARD BRINSLEY HINDS

In September, 1835, H.M.S. *Sulphur* was commissioned by Captain Beechey to make another trip around the world. Captain Beechey was invalided at Valparaiso, and was succeeded by Acting-Commander Kellett, who was superseded by Edward Belcher.

Twice the expedition reached the west coast of North America (in 1836 and in 1839), and here numerous surveys were conducted. But the nature of the voyage did not allow extensive collections and, in fact, the last paragraph of instructions as given in Commander Belcher's journal states: "Large collections of natural history cannot

\* Several papers by Nuttall (and also Townsend) appear in *J. of the Acad. Nat. Sci. of Phila.*, vols. 7 and 8.

be expected . . . nor indeed would minute inquiries on . . . [this subject] be at all consistent with the true objects of the survey. . . ."

But the commander himself was an observant man, and he constantly notes the characteristic fauna and flora of the region.\* On board as surgeon was Richard Brinsley Hinds, who, like Pickering, was a trained medical man whose real love was botany and who, again like his colleague, was particularly interested in geographical botany. To this study he assiduously applied himself while on board the *Sulphur*. His scholarly written results appear in the second volume of Captain Belcher's *Narrative*.<sup>40</sup>

According to Frederick Brendel,<sup>41</sup> a Mr. Barclay, a botanist in the service of Kew Gardens, accompanied the expedition and was aided by a Dr. Sinclair. We have failed to corroborate this and their names do not appear on the ship's roll. The botanical collection was described by George Bentham in the *Botany of the Voyage of H.M.S. Sulphur*, 1844.

#### KARL THEODORE HARTWEG

Some eleven years after the London Horticultural Society had first sent Douglas to America, another collector was sent by them to the new country, a young German botanist, Karl Theodore Hartweg.<sup>42</sup>

Hartweg was born June 18, 1812, at Karlsruhe, Germany, a city noted for its parks and botanic garden. He was the descendant of a long line of gardeners and received an excellent education in botany. As a young man he was employed by the Paris Jardin des Plantes. Later he was employed by the London Horticultural Society and sent by them to Mexico in 1836 to collect seeds and plants for introduction into England. He spent seven years collecting in Mexico, Central America, and northern South America, returning to England in 1843.

Of his work Jepson says, "The travels of Hartweg resulted in the most extensive collection, made by a single individual, that came from Mexico and tropical America in the first half of the century."<sup>43</sup> Among the rare plants he found were orchids and several new species of pine. His own journal describes in detail the botany of the region explored.<sup>40 41</sup>

\* Commander Belcher (then Lieutenant Belcher) materially assisted Messrs. Collie and Lay on Beechey's first voyage and received high praise from the latter for this work.

The Society was so pleased with his work that they sent him to California on a similar expedition in 1845. He arrived at Vera Cruz in November of that year and crossed Mexico to Mazatlan on the Pacific coast. Because of the difficulties at the time between England and the United States over possession of Alta California, Hartweg was unable to get passage to California until May, 1846, arriving in Monterey June 7. Because of the political disturbance, Hartweg remained near Monterey but collected many valuable specimens, notably the Monterey Cypress.<sup>33</sup> Later in the year he made extended journeys to San Francisco, the Sacramento Valley as far north as Chico, and excursions into the Sierra foothills, where he collected *Caenothus prostratus* for the first time. Other trips took him into the High Sierra. From here he ranged southward to Soledad and San Antonio in the Salinas Valley. Going into the Santa Lucia Mountains, he found the long-sought-after Santa Lucia fir, "*Abies venusta*" (*bracteata*),\* but the cones were not ripe and had been frost-bitten, so that he was unable to send seeds to England. He was later severely criticized by the Society for not obtaining these seeds when he returned with his collections in 1848. George Bentham published on his collections in his *Plantae Hartwegianae*.<sup>7</sup> Eighty-one species were described as new.

Following the California expedition, which was not entirely satisfactory to the Society, as noted above, Hartweg became Director of the Grand-Ducal Gardens, Baden, where he died on February 3, 1871.

#### DUFFLOT DE MOFRAS

After the expedition of La Pérouse, the French Government did not evince much interest in the western coast of America, as they were occupied by the readjustment following the Napoleonic wars. During this period, as we have seen, the Russian, Spanish, English and American governments all were engaged actively in the exploration of the region. But from around 1830 onwards France once again resumed her dreams of colonial expansion in America. Numerous expeditions were sent out to ascertain the political and economic conditions of the Pacific coast. Among those sent out, Count Eugene Dufflot de Mofras, a young diplomatic attaché, was one of the few who made any study of the botany or zoology of the region. Dufflot de Mofras<sup>37</sup> was born at Toulouse on July 5, 1810. He special-

\* First discovered by Coulter.

ized in science, but at eighteen was appointed an attaché to Madrid and so began his diplomatic career.

In 1840 he was sent to Mexico for the purpose of inspecting the Pacific coast for the French. The results of his investigations which were published are now of great historical importance and give an interesting account of the land as he found it. The natural history portion of the work is of little value, however, as he merely listed the principal species of plants and animals noted, and these, of course, had already been studied by earlier explorers. During his stay on the Coast he met Lieutenant Charles Wilkes, who was making a similar investigation for the United States Government, the scientific results of which were far more valuable. The British were likewise quietly investigating at the same time. Their representative was Sir George Simpson, Governor of the Hudson's Bay Company. In 1842 Duffot de Molras returned to France, where the remainder of his life was occupied with political writings. He died in 1884.

#### UNITED STATES EXPLORING EXPEDITION

As early as 1827—after von Krusenstein's reports were made public and some time before Captain Beechey had returned\*—John N. Reynolds was ardently fostering the idea of a United States Exploring Expedition. It is not for us to go into the details of this first and greatest naval expedition to leave our shore; suffice it to say that after a decade of haggling and procrastinating on all sides, the expedition finally set sail from Hampton Roads on the eighteenth of August, 1838. Six ships took part under the command of Lieutenant Charles Wilkes, U.S.N. Much discussion centered around this man, both before and after the expedition. He was undoubtedly a resolute and upright individual, inclined to be arbitrary and often at variance with officers and crew. Probably the most just evaluation of the man may be found in the words of J. D. Dana, a member of the scientific staff, who wrote, "... an excellent commander. Perhaps no better could have been found in the navy at the time."<sup>1</sup>

On the official roster are found the names of the following scientists: Charles Pickering, William D. Brackenridge, J. P. Couthouy, J. D. Dana, T. R. Peale and William Rich. It would be quite out of the question and perhaps unnecessary to give this expedition (and its members) its due, for to place it in proper perspective would fill

\* And four years before Darwin sailed with Captain Fitzroy.

a volume in itself. A glance at the names above will convince the reader this is so. Although the greater part of the voyage was spent away from the west coast, great care was taken in the survey of this region for obvious reasons. On April 6, 1841, we find the flagship off the Columbia River, and until the first of November, when they set sail from San Francisco, the expedition was engaged on the Pacific coast.

The oldest and most distinguished member of the scientific staff was Charles Pickering, M.D. Born in 1805, Pickering was a native of Pennsylvania. He attended Harvard but left before graduation. He took his M.D. degree from Harvard Medical School in 1826. A strong taste for botany and zoology showed itself in early boyhood and led to his final choice of profession. He went to Philadelphia ostensibly to carry on his medical career, but it appears more likely that he was drawn there by the facilities offered for further studies in natural history. At any rate, he soon became active at the Academy of Natural Sciences, where he served as curator and librarian and quickly got the reputation of being one of the most erudite of all the young naturalists. Those who knew him state (and a study of his last great work will testify) that his knowledge "... was encyclopedic and minute; his bent was toward a certain subtlety and exhaustiveness of investigation. . . ."

Two years before the United States Exploring Expedition sailed (when it was first organized under Commodore William Ap-Catesby Jones) Pickering's reputation was such that he was selected as chief zoologist. He did not, apparently, retain this title, as later others were added to the scientific staff; yet Asa Gray, who was closely associated with the enterprise\* states that the fame of the expedition rests largely on the collections of Pickering and his associate, Dana. Pickering was the ichthyologist, but his special study was anthropology and geographical distribution of plants and animals as affected by man. To this subject he devoted the rest of his life; in 1848 appeared his volume on *The Races of Man and Their Geographical Distribution*, forming the ninth volume of the Wilkes Expedition reports. His later work entitled *The Geographical Distribution of Animals and Plants*, which was to be the fifteenth volume of the series, was not published as such because of suspension of government subsidies.

\* Asa Gray was to accompany the expedition but resigned.

After his death (at the age of seventy-three) his monumental work, the *Chronological History of Plants: Man's Record of his own Existence Illustrated through their Names, Uses, and Companionship*,<sup>67</sup> was published and furnishes ample evidence of the industry, learning and astute powers of coordination possessed by this man.

The name of James Dwight Dana is too well known to call for discussion in this paper. He originally shipped as mineralogist of the expedition, but as a result of the illness and resignation of Mr. Couthouy much other work devolved on this able scientist.

In the words of his biographer,<sup>68</sup> his was

"... the life ... of a distinguished naturalist, successively an explorer, an investigator, a writer, an editor, and a teacher. His versatility is as noteworthy as his longevity. Gifted with uncommon powers of observation, memory, comparison and reasoning, he devoted them to the sciences of mineralogy, geology and zoology."

Such was the man who at the age of twenty-seven was shipwrecked on the northwest coast of America. He wrote *Geology*, volume 9, *Zoophytes*, volume 7, and *Crustacea*, volume 13, of the expedition's memoirs.

A little-known yet interesting member of the United States Exploring Expedition is Titian Ramsay Peale, listed in the official roster, along with Pickering, as naturalist to the expedition. Peale, the youngest of five brothers, was born in Philadelphia Hall in the year 1800. His father, Charles Wilson Peale, is known today as the artist who painted the earliest known portrait of Washington and as the founder of the Philadelphia Museum (known as Peale's Museum). From his father Titian received his early instruction as a draughtsman and naturalist. Not much is known of his boyhood beyond the notice that "Titian is a good boy and goes to school constantly."<sup>69</sup> That he was early recognized as a young man of some ability is evidenced by his election to the Academy of Natural Sciences of Philadelphia while still in his 'teens and by the fact that in the autumn of the same year (1817) he took an active part in an expedition sponsored by the Academy. Two years later he was assistant naturalist to the Long Expedition. On this trip Peale collected avidly and made 122 sketches. An able artist, he is responsible for the illustrations in volumes 1 and 4 of Bonaparte's *American Ornithology*<sup>70</sup> and for volumes 1 and 3 of Say's *American Entomology*.<sup>71</sup> The



latter called forth the statement that "... for beauty and elegance this work surpasses any other that has been published in this country."<sup>65</sup>

In 1831 Peale accompanied the Burrows Expedition to South America, where he again demonstrated his excellence as a first-rate field naturalist.

On July 19, 1833, he became a member of the American Philosophical Society, and some years later he received his appointment as naturalist to the Wilkes Expedition. Peale, with Dana, was attached to the ship *Peacock*, which was wrecked on the bar at the mouth of the Columbia River, May 18, 1840.

Peale, with Dana, Rich and Brackenridge, accompanied a party up the Willamette River, over the dividing mountains, and past Mt. Shasta to the upper reaches of the Sacramento River and thence to San Francisco.

There is evidence of much friction both between the command and the scientific staff and among the naturalists themselves.\* Commander Wilkes charged that the scientific members failed to take into account the multiple purposes of the expedition and that "... each [man] would naturally look upon his own [work] as the most important."<sup>66</sup> Yet Wilkes mentions that, with one exception, the scientific staff was to be commended. This exception seems to be the unfortunate Peale. For some reason, during the preparation of his reports, he was denied the opportunity of consulting his collections, and the results appeared as volume VIII of the expedition reports without the plates he had prepared for it. Wilkes, feeling it failed to come up to the standard of the others, ordered it suppressed; ten years later John Cassin was called upon to supervise another volume (also numbered volume VIII)<sup>67</sup> and not only had the benefit of examining the original collection, but a glance at the atlas shows he incorporated many, if not all, of Peale's colored plates.\*\* All in all, Peale seems to have been rather badly treated; his notes indicate he was an astute observer, and what little information exists leads one to believe he was most agreeable.

\* After their return there were charges of plagiarism involving Pickering and Coultour.

\*\* "Stone, of the Academy of Natural Sciences of Philadelphia, on the authority of Jardine's *Contributions to Ornithology*, published in 1852, says that only 100 copies of each of the Reports of the Exploring Expedition were published by the Government, but that the authors were allowed to have printed as many more as they chose, for their personal use, and that Peale was the only one who did not avail himself of this privilege. Only 90 of his reports were distributed by the Government, the remainder of the edition being destroyed by fire."<sup>68</sup>

Respecting Couthouy and Rich, very little can be learned. Rich is said to have been the senior botanist, but his report, too, was mysteriously repressed. Couthouy, due to illness, probably never reached western America.

William D. Brackenridge\* was a Scotsman born near Ayr in 1810. He served as a gardener in Edinburgh and later was attached to the Botanical Garden in Berlin. He came to America in 1837, but how he became a member of the Wilkes Expedition is not fully known. He was a quiet but earnest man, wholly bent on collecting his beloved plants. He is responsible for volume XVI of the expedition's reports.

While on the way over the mountains from the Willamette Valley to San Francisco, the party met a band of Indians that caused them some alarm. It is said that while running to safety Brackenridge spotted a new plant, hesitated long enough to grab a handful of foliage, then dashed on to camp—he had collected *Darlingtonia californica*! Brackenridge died February 3, 1893.

It is difficult to evaluate accurately the scientific accomplishment of the men of the Wilkes Expedition on the west coast. Owing to the action of the Government in suspending subsidies, only a few copies of the expedition's memoirs were printed. So many obstacles were put in the way that it is a wonder, perhaps, that any successful reports of the findings appeared. Many new forms were discovered by this—our country's first—organized corps of naturalists, and much of their work remains unchallenged today.

The United States Exploring Expedition marked the beginning of a new era in the development of the Far West, the most striking period in its history. While many of its secrets were made known to the world by the men whose individual efforts we have followed in these pages, much remained to be discovered; the unbelievable extent of its mineral riches was unknown, so, too, the marvelous fertility of its wide valleys, the trackless timbered forests of its mountain slopes. Hasty coastal surveys, however, were giving place to detailed overland expeditions. Heretofore the natural history inquiries were incidental in the extreme; the collections were almost invariably due to the zeal of some individual—usually the ship's surgeon. To be sure, a few expeditions such as that captained by the ill-fated La Pérouse, were magnificently equipped for extensive

\* Listed as horticulturist and again as assistant botanist.

studies in natural history, but they were rare exceptions. The vast amount of material that made its way into Europe in the years preceding 1840 was the accumulation of the bits contributed by such indefatigable naturalist-explorers as Steller, Menzies and Douglas, to mention but three. But much of the groundwork was now done—a lattice-work of observations that stretched from the frozen wastes of the north to the barren coast-lands of Baja California and from mountain peak to desert floor. The time for organization and specialization was near at hand. Even now Frémont was preparing to leave on a carefully planned exploring expedition, and the great railroad surveys of 1853 to 1856, intensive studies which followed methodically the various parallels westward to the Pacific, were already projected.

This period also saw a tumultuous increase in the population. Lured by gold, thousands came from all corners of the earth, many remaining to become permanent settlers. Among these were a few who sought treasures above the soil, kindred souls with David Douglas and José Mociño, and it was but a matter of time before a nucleus of such men was formed, commonly seeking the promotion of science in a new world. So was born the California Academy of Sciences.

Thus we find, after a lapse of some three centuries, since the disappearance of the Aztec gardens, once again the appearance of natural history studies indigenous to the soil.

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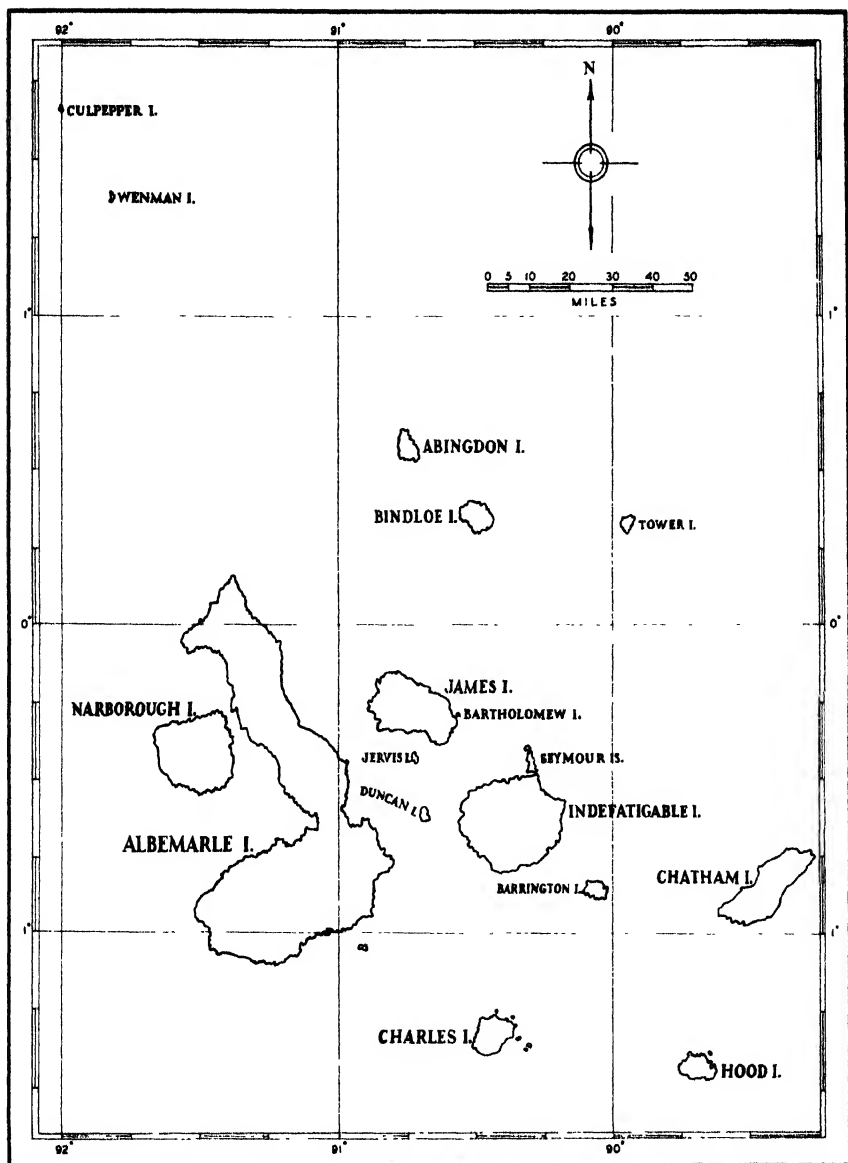
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Map of the Galapagos Islands

# The Galapagos Finches (Geospizinae)

A Study in Variation

BY

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SAN FRANCISCO

CALIFORNIA ACADEMY OF SCIENCES

1945

OCCASIONAL PAPERS NO. XXI  
OF THE CALIFORNIA ACADEMY OF SCIENCES  
Issued May 30, 1945

COMMITTEE ON PUBLICATION

DR. F. M. MACFARLAND, *Chairman and Editor*

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# The Galapagos Finches (Geospizinae)

## A Study in Variation \*

### INTRODUCTION

#### PROCEDURE AND ACKNOWLEDGMENTS

The present study of variation in the remarkable endemic finches of the Galapagos Archipelago is based, first, on an expedition to the islands from mid-December 1938 to early April 1939, and second, on a study of the skins of Geospizinae in American and British museums. The writer wishes gratefully to acknowledge grants made by the Royal Society, the Zoological Society of London, and the Elmgrant Trustees, Dartington Hall, which made this study possible. The expedition had three main fields of inquiry: (1) breeding behavior, (2) ecology, (3) hybridization. The first two, breeding behavior and ecology, concerning which extremely little was known before, were covered adequately, but far less success attended breeding experiments. Attempts to cross-breed the birds in aviaries on the Galapagos failed. Further, when the time came to capture birds for transportation to England, they proved much harder to catch than earlier in the year, so that only thirty-one individuals of four geospizid species were obtained. These traveled badly, so that on arrival in Panama it seemed extremely improbable that they would survive the journey to England. Accordingly we cabled to Dr. Julian S. Huxley, and, with his approval, the birds were transferred to the California Academy of Sciences in San Francisco.

The field expedition consisted of: W. Hugh Thompson, who assisted the writer with the field study of the finches; L. S. V. VENABLES, who worked on birds other than the Geospizinae; Richard

\* The present paper was written by David Lack in the fall of 1939, which time marked the beginning of World War II. Working under pressure, the author left the rough manuscript in this country and returned to England to enter military service before the close of the year. During the year following he attempted to revise the copy but under the circumstances this proved a difficult task. Members of the staff of the California Academy of Sciences have made a number of changes and corrections and prepared the tables, histograms, and other illustrative features incorporated into the work. As would be expected, however, many inconsistencies and conflicts in style have arisen. The reader is asked, therefore, to bear this in mind when critically reviewing the results contained herein.—EDITOR



Leacock, photographer; and Mr. and Mrs. T. W. J. Taylor, botanists. The main party arrived at Guayaquil, Ecuador, in late November 1938, and reached the Galapagos on December 14, leaving again on April 3, 1939. The writer worked on Chatham Island from arrival until January 29, January 30 was spent on Hood, January 31 to April 2 on Indefatigable, and April 3 on Tower Island. W. H. Thompson worked with the writer on Chatham until January 10, then on Indefatigable from January 11 until the middle of February, when he became ill. Up to the time of his illness, W. H. Thompson shared equally in the field observations on breeding behavior and ecology, and may therefore be considered equally responsible with the writer for the data upon which Sections II and III are based. The majority of the life histories had been worked out before he became incapacitated. Unfortunately, since my return to England after the war started, I have been unable to get in touch with him for writing up these sections. However, I have had a copy of most of his original field notes from which to work. I should like to record here my gratitude to him for his invaluable assistance. I also thank L. S. V. VENABLES and the other members of the party for their assistance with some of the observations, and help in catching the birds. T. W. J. Taylor is responsible for the botanical identifications in Section III, and some of the habitat photographs.

Thanks are particularly due to Dr. Julian S. Huxley, who took a continuous and extremely stimulating interest in the expedition and helped in innumerable ways. We must also thank the Ecuadorian government for permission to stay on the islands, and the British Consul and Vice Consul in Guayaquil for their assistance in arranging our passage to the Galapagos, permits, customs, and other formalities. The British Ornithologists' Union, the British Ornithologists' Club, and certain private individuals further assisted the expedition by grants to L. S. V. VENABLES. We also express our appreciation to various inhabitants of Chatham and Indefatigable for their assistance, in particular Señor Cobos, in whose house we stayed on Chatham, and the Angermeyers and the Küblers on Indefatigable.

On arrival in San Francisco, the thirty surviving captive birds were placed in the care of Mr. Eric C. Kinsey. Subsequently they were moved to aviaries in the California Academy of Sciences. When in the United States, the writer took the opportunity of

studying various collections of Geospizinae, for which thanks are due especially to the California Academy of Sciences,<sup>1</sup> with its large series which made the statistical investigation of variation possible, also to the American Museum of Natural History<sup>2</sup> including the Rothschild Collection, the United States National Museum,<sup>3</sup> Stanford University Museum of Natural History,<sup>4</sup> the Museum of Comparative Zoology,<sup>5</sup> and later, the British Museum (Natural History),<sup>6</sup> for their kind hospitality and for providing the writer with every facility for work. The Carnegie Museum,<sup>7</sup> the University of Michigan,<sup>8</sup> the Museum of Vertebrate Zoology,<sup>9</sup> the Field Museum of Natural History,<sup>10</sup> and the Philadelphia Academy of Natural Sciences<sup>11</sup> kindly allowed me to examine their smaller series.

Many American workers helped me to clarify my ideas in discussion of various aspects, particularly the staff of the California Academy of Sciences, including Dr. Robert C. Miller, the late Mr. James Moffitt, Dr. Robert T. Orr, Mr. John Thomas Howell, and others; Dr. Alden H. Miller of the University of California; and Dr. Ernst Mayr of the American Museum of Natural History.

After my return to England on September 30, in addition to the continued interest of Dr. Julian S. Huxley, I have particularly to thank Dr. R. A. Fisher, of the Galton Laboratories, for his help with the statistical data.

The manuscript was sent to the California Academy of Sciences in May 1940, and I am deeply indebted to the editors for preparing the final copy and for seeing the paper through the press, a task which, owing to the war, I could not undertake myself.

### THE GALAPAGOS ISLANDS

The Galapagos Islands are a group of volcanic islands lying on the Equator, some six hundred miles to the west of Ecuador, to whom they belong. They have been described so often that little need be said here. For those seeking a general description, Murphy (1936, pp. 296-303) gives an accurate summary with references. The islands are in the coolest equatorial region in the world, being in the path of the Humboldt current coming up from the Antarctic. Southeast trade winds blow for three-quarters of the year, while from about December to March, but varying greatly in different

<sup>1</sup>C.A.S.; <sup>2</sup>A.M.N.H.; <sup>3</sup>U.S.N.M.; <sup>4</sup>Stanford Coll.; <sup>5</sup>M.C.Z.; <sup>6</sup>B.M.; <sup>7</sup>C.M.; <sup>8</sup>U.M.; <sup>9</sup>M.V.Z.; <sup>10</sup>F.M.; <sup>11</sup>P.A.N.S.

years, there is a rainy season with alternating periods of thunder storms and calms. The coastal belt of all the islands is thornbush in which tree cacti (*Opuntia* and *Cereus*) are conspicuous; the largest islands have humid forests at higher altitudes, and the tops of Chatham, Indefatigable, and Albemarle are covered with grass, ferns, etc. The map shows the positions and English names of the islands. Although all now have Spanish names, the English names are so much a part of the literature that it seems advisable to retain them. The distances between certain of the islands, which are of interest concerning the production of island forms, are given in Text Table 1.

Table 1

Distances between various Galapagos Islands

(expressed in nautical miles and, for larger distances, to nearest 5 miles)

	San Juan	Tower	Indio	Isle	Indefatigable	Albemarle	Chatham	Hood	Charles	Crossman
Culpepper	18.5									
Tower	125		28	50	45*		70			
Abingdon	77	45	13	40		38		105		
James		50	32		10	10				
Jervis				5	13	14				
Daphne				13	4					42
Indefatigable		45*	50*	10		15	40		30	70
Duncan				12.5	7	10				
Albemarle	75		42	10	15				30	4
Narborough						2				
Barrington							25		30	
Chatham		70			40			25	50	
Charles					50	30	50	37		30
Gardner, near Charles									4	

\*Estimated from South Seymour.

The islands first became famous through the visit of Charles Darwin in H.M.S. "Beagle" in 1835. Darwin was the first to collect the endemic Galapagos finches, and, as one can gather from *The Origin of Species* . . . , they were one of the most important influences in assisting him with his conclusions on evolution. The special peculiarity of these finches is that, unlike most insular birds, where one different form is found on each island, "each separate island of the Galapagos Archipelago is tenanted, and the fact is a marvellous one, by many distinct species . . ." (Darwin, 1888,

p. 355). This state of affairs has given rise to much speculation which is here discussed primarily in the last section. Further, the taxonomy of the group is abnormally complicated. In this respect, the present study owes much to the extremely sound and careful work of the late Mr. H. S. Swarth (1931), who cleared up most of the pre-existing confusion. The Galapagos finches are not, of course, the only interesting birds on the islands, but they are the only ones considered here; for a general account of other bird problems, see Swarth (1934).

The present study is divided into the following six sections:

- I. Taxonomy
- II. Breeding behavior
- III. Ecology
- IV. Coloration
- V. Variations in bill and wing
- VI. General evolutionary problems

## SECTION I. TAXONOMY

This paper is concerned primarily with variation in the *Geospizinae*, not with their nomenclature. As a basis for the latter, I have used the latest review of Swarth (1931, pp. 137-270), slightly modified by Hellmayr (1938, pp. 130-146). At first I intended to make no changes; but consistency in nomenclature is a valuable guide to the degree of variation, hence I have made certain modifications, mostly relating to the merging of island forms admitted by Swarth. In each instance, my larger series of measurements shows that there is a significantly different mean size for the populations concerned; but in cases where less than 75 per cent of the specimens are safely distinguishable (and often less than 50 per cent are distinguishable) the forms have been merged. Otherwise, for consistency, one would have to name a number of new forms which differ to about the same extent. The main object of classification is convenience of reference, and all such incompletely differentiated forms seem best designated by the name of the species together with that of the island or islands on which they occur. Many species of *Geospizinae* show slight differences in mean size of bill and wing on almost every island, but with wide overlapping in extremes between birds from different islands. Thus it would be absurd to designate all such cases by formal scientific names.

Although the present classification seems more consistent than any previous one, complete consistency is unattainable. The treatment of *Geospiza scandens* (*sensu stricto*) is particularly difficult. In the *Camarhynchus psittacula* group, I have provisionally retained Swarth's nomenclature, although it is not altogether consistent with that adopted elsewhere, since further collecting is needed to establish the position of some forms.

Evidence for nomenclatural changes is only summarized in this section, details, including measurements, being given later, while for full descriptions of the genera and species the reader is referred to Swarth (*supra cit.*).

### THE FAMILY "GEOSPIZIDAE"

Swarth (1929) placed the Galapagos finches, together with *Pinaroloxias* of Cocos Island, into a separate family, but the characters he gave hardly justify this. The only diagnostic feature, the

long fluffy feathers of the lower back, is found in many other tropical birds. On anatomical grounds, Sushkin (1925) and Lowe (1936) agree that the Galapagos finches are true Fringillidae, closely related to the West Indian *Tiaris* or *Euetheia*. Hence they can be placed in one of the existing subfamilies of the Fringillidae. Hellmayr (1938, p. 130), however, prefers to use the subfamily designation, Geospizinae, for the group, a term which for convenience is employed in this paper.

### GENERA

The writer is in full agreement with Swarth (1931) as regards the application of generic names. The following field observations confirm these conclusions in several ways:

1. *Certhidea* has breeding habits almost identical with the other Geospizinae, being clearly of this group and not, as was once thought, a member of the family Mniotiltidae.
2. *Cactospiza pallida* was formerly united in the same genus with *Geospiza scandens*. Song and feeding habits fully confirm the view that *scandens* is related to other species of *Geospiza*, while *Cactospiza* seems most closely related to *Camarhynchus*.
3. *Platyspiza* has a different song and different feeding habits from *Camarhynchus*, with which it has often been united.

### SPECIES

With reference to the arrangement and concept of species, Swarth (1931) cleared up most of the previous confusion, and, with few exceptions, his treatment is followed here. The distributions are summarized in Text Table 2, in which the birds are classified under "superspecies," the convenient term proposed by Mayr (1931*b*, p. 2) for related forms which replace each other geographically, even though sometimes distinct enough to be named as separate species. The term closely corresponds with Rensch's "Artenkreis."

The Geospizinae have been so thoroughly collected that the table probably contains few omissions. There are large series of each form available from the various islands except in a few cases indicated in the table by an asterisk, or by a small letter in brackets. These exceptions probably represent stragglers from one island to another which have not established themselves. Some of these may possibly prove to be resident.

Table 2

## Distribution of the Geospizinae

Species	Culpepper	Newman	Tower	Abington	Bindloe	Albemarle (+Harborough)	James	Indefatigable	Barrington	Contham	Hood	Charles	Cocos Island
<i>Geospiza magnirostris</i>		x	x	x	x	x	x	x	x			x*	
<i>Geospiza fortis</i>		x*	x*	x	x	x	x	x	x	x	x*	x	
<i>Geospiza fuliginosa</i>		x*		x	x	x	x	x	x	x	x		
<i>Geospiza difficilis difficilis</i>			x	x									
" " <i>debilirostris</i>						x*	x	x					
" " <i>septentrionalis</i>	x	x											
<i>Geospiza scandens</i>				x	x	x	x	x	x	x		x	
<i>Geospiza conirostris conirostris</i>											x		
" " <i>propinqua</i>			x										
" " <i>darwini</i>	x												
<i>Platyspiza crassirostris</i>				x	x	x	x	x		x		x	
<i>Camarhynchus psittacula psittacula</i>							x	x	x	x*		x	
" " <i>habeli</i>				x	x								
" " <i>affinis</i>						x	x*	x*					
" " <i>pauper</i>												x	
<i>Camarhynchus parvulus parvulus</i>		x*		x		x	x	x	x			x	
" " <i>salvini</i>										x			
<i>Coccothraupis pallida pallida</i>						x	x	x				x*	
" " <i>striaticeps</i>										x			
<i>Coccothraupis heliobates</i>						x							
<i>Corvinidae olivacea becki</i>	x	x											
" " <i>mentalis</i>			x										
" " <i>fusca</i>				x	x								
" " <i>olivacea</i>						x	x	x					
" " <i>bifasciata</i>									x				
" " <i>luteola</i>										x			
" " <i>cinerascens</i>											x		
" " <i>ridgwayi</i>												x	
<i>Pinaculoxys inornata</i>													x

\*Species has occurred on island, but perhaps only as a straggler.

## Geospiza magnirostris Gould

Plate 1, figures 1 and 2

Not separated into island forms. The birds from Culpepper Island placed by Swarth (1931, pp. 149-150) in this species are here transferred to the *conirostris* group. The series in the Rothschild Collection shows that the bill, although heavy, is much more

like *conirostris* than *magnirostris* in shape and the female plumage also differs from that of *magnirostris*. By referring them to *magnirostris*, Swarth (*op. cit.*, p. 206) also had to list *G. conirostris propinqua* for Culpepper Island. Actually, all seem assignable to one variable form for which I revive the name *Geospiza conirostris darwini* Rothschild and Hartert. The latter authors (1899, p. 158) described this form as *Geospiza darwini* and noted its similarity in bill to *propinqua*. Later (1902, pp. 389-390) they considered it a subspecies of *conirostris*.

One specimen of *Geospiza magnirostris* from Charles Island examined in the collection of the U.S. National Museum appears doubtless to have been a straggler. Swarth (*op. cit.*, p. 162) considered it an abnormal example of *fortis*, but I cannot separate it from *magnirostris*.

The three black males in the series of *G. magnirostris* collected by Darwin are all slightly larger than any collected since. Clearly a measurable evolutionary change has occurred since Darwin's visit. This raises an issue in nomenclature which, while common in paleontology, is rare in ornithology, although liable to become more common in the future. Each species clearly has an extension in time as well as in space, and since modern *magnirostris* are of the same general type as those of Darwin's day, it seems easier to retain the same name, even though there is no overlapping in measurements. It is unfortunate that the island from which Darwin obtained these specimens is in dispute. The specimens were originally attributed to either Charles or Chatham Island, in which case they represent an extinct form, as *magnirostris* is unknown from these islands today. I agree, however, with Swarth that it is more probable that the specimens came from James. Darwin undoubtedly collected on James, as one of his *G. scandens* must have come from there. If *magnirostris* was as common on James at the time of Darwin's visit as it is today, he could not possibly have overlooked it there. Darwin, however, also collected some smaller specimens of the *magnirostris* type which he described as *G. strenua*; these might have come from James. There is the additional point that Darwin collected two specimens of *Geospiza nebulosa* which I ascribe to an extinct form of the *G. difficilis* group. It is conceivable that the human inhabitants of Charles or Chatham Island directly or indirectly brought about the extermination of both Darwin's *G. magnirostris* and *G. nebulosa* between the time of



his visit and that of the next collector; for at the time of Darwin's visit Charles had but recently been colonized and Chatham had not yet been settled.

### **Geospiza fortis** Gould

Plate 1, figures 3 and 4

This extremely variable species cannot be separated into island forms. Birds from the northern islands, north Albemarle, James, Jervis, Bindloe, and Abingdon, are smaller than those from the more southerly south Albemarle and Chatham, but the birds on Charles, the most southerly island of all, and also those on Indefatigable include all types between these forms.

Fourteen specimens from Hood, one from Wenman (California Academy of Sciences), and one from Tower (Carnegie Museum) were presumably stragglers. Only the Academy expedition has ever collected this species on Hood, and all the males in this series are in immature plumage.

Swarth (1931, pp. 152-154) gives a full list of the numerous synonyms of this species. The writer agrees with all of these excepting *Geospiza bauri*, *G. brevirostris*, and *G. nebulosa*, which are discussed later.

### INTERMEDIATES BETWEEN *Geospiza magnirostris* AND *Geospiza fortis*

*Geospiza magnirostris* and *G. fortis* differ from each other solely in size and in relative size of bill, overlapping in all measurements. Some specimens with mostly intermediate measurements can be identified if in one character they are typical of one or the other species. The length of the culmen is the most reliable guide. In Section V, I include a set of measurements of large *fortis* and small *magnirostris*, in order to illustrate the difficulties involved. In most cases, I have assigned the specimen to one or the other species, but in some instances where my decision is contrary to the opinion of other workers, I do not claim complete certainty of my identifications. Particularly difficult are three females and the type, a black male, of "*Geospiza bauri*" from James Island, while two Bindloe Island specimens are similar. Swarth correctly identified the many specimens referred by later collectors to the form *bauri* as belong-

ing to the widely variable *fortis*. These James and Bindloe Island specimens, however, are more puzzling, since they greatly exceed the maximum normally attained by *fortis* on these islands, but are small for *magnirostris*. Possibly they are *fortis* which wandered from one of the southern islands, but they might be unusually small *magnirostris*, or hybrids.

### INTERMEDIATES BETWEEN *Geospiza fortis* AND *Geospiza scandens*

Swarth synonymized *Cactornis brevirostris* Ridgway with *Geospiza fortis*. It is represented by a partially black male from Charles Island in the U.S. National Museum collection, while a female from Indefatigable in the Rothschild Collection (No. 516928; see also Rothschild and Hartert, 1899, p. 159) can possibly be placed with it. These specimens are intermediate between *fortis* and *scandens*. Clearly *Cactornis brevirostris* is not a valid species, but whether the specimens are aberrant variants of either *Geospiza fortis* or *G. scandens*, or are hybrids between them, is uncertain. Another unsexed specimen from Indefatigable in the U.S. National Museum (No. 77756) is also intermediate between *fortis* and *scandens*, but is much nearer to *scandens* than is the type of *Cactornis brevirostris*. A fourth specimen, a black male from Charles Island, is also intermediate between these two species. For measurements and details, see Section V.

### *Geospiza fuliginosa* Gould

Plate 2, figures 1 and 2

The rare *Geospiza fuliginosa minor* Rothschild and Hartert of Abingdon and Bindloe islands was described on the basis of its smaller wing, but overlapping with typical *fuliginosa*, however, is too great in the writer's opinion to justify this. Swarth placed the four specimens taken on Wenman Island under *minor*. Although all have small wings, the male has an unusually large bill, and this bird and one of the females show slight plumage variations in the direction of *Geospiza difficilis septentrionalis* of Wenman Island. Perhaps they were stragglers, and conceivably hybrids, not necessarily first generation, with *septentrionalis*.

### INTERMEDIATES BETWEEN *Geospiza fortis* AND *Geospiza fuliginosa*

The differences between *Geospiza fortis* and *G. fuliginosa* are more clear-cut than are those between *G. fortis* and *G. magnirostris*. Birds intermediate in character in the Rothschild Collection were described by Ridgway as *Geospiza harterti*. The type of this form, from Chatham Island, is possibly an aberrant specimen of *fuliginosa*, but the bill is abnormally deep and the wing is long. It is well below the normal minimum size of *fortis* on Chatham Island, and does not suggest a hybrid between the two.

Many specimens from the tiny islet of Daphne (between Indefatigable and James) conceivably represent an extremely small form of *fortis*, as Swarth suggested on the basis of specimens from Daphne in the collection of the California Academy of Sciences. It seems highly improbable, however, that *fortis* should be so very much smaller here than on either of the two neighboring islands only a few miles away. More probably, they are a hybrid population of *G. fortis*  $\times$  *G. fuliginosa*. Birds from Crossman Island, off east Albemarle, are somewhat smaller than those from Daphne, and may also be of hybrid origin. Two others labeled "east Albemarle" seem referable to the Crossman Island form, and perhaps were obtained there. These are all discussed in the section on measurements.

A black male from Hood in the Rothschild Collection (No. 517663) has an unusually deep bill for *fuliginosa*, but, especially since *fortis* is normally absent from Hood, it is probably to be regarded as an aberrant specimen of *fuliginosa*. Two others labeled "*harterti*" from Hood Island are typical *fuliginosa*, the same applying to two specimens from Gardner Island near Charles.

The type of *Geospiza dentiostriis* Gould was, I believe, correctly assigned by Swarth to *fortis*. In the British Museum there is a black male from Charles Island which was originally labeled *fortis* and later *dentiostriis*, the measurements of which approach "*harterti*." Also, there is a similar specimen in the Museum of Comparative Zoology (No. 134650). These I consider to be unusually small examples of *fortis*. An unsexed bird from Duncan Island in the British Museum (No. 99.9.-1.293) has an abnormally deep bill but is probably an aberrant specimen of *fuliginosa*. Hence, except on the tiny islets of Daphne and Crossman, intermediates between *fortis* and *fuliginosa* are quite rare.

***Geospiza difficilis* superspecies**

Plate 2, figures 3 and 4

Swarth included here the species *acutirostris* Ridgway of Tower Island, *difficilis* Sharpe of Abingdon Island, *debilirostris* Ridgway of James and Indefatigable islands, and *septrionalis* Rothschild and Hartert, the last separated into the typical race on Wenman Island and *Geospiza s. nigrescens* Swarth on Culpepper Island. Hellmayr (1938, pp. 132-134) lists all of these as subspecies of *Geospiza difficilis*, since they replace each other geographically and are quite similar in appearance. *Geospiza acutirostris* and *G. difficilis* are not separable by plumage, and, although the former tends to have a smaller bill, measurements overlap so much that even subspecific separation seems unjustified. The two forms of *septrionalis* also overlap too much to justify separation. Accordingly, three subspecies of *G. difficilis* are admitted here, namely *G. d. difficilis* of Tower and Abingdon islands, *G. d. debilirostris* of James and Indefatigable islands, and *G. d. septrionalis* of Culpepper and Wenman islands.

One black male *debilirostris* from south Albemarle in the Rothschild Collection was possibly a straggler, as no others have been collected there, but it may well prove to be resident locally. High up on Narborough Island, Beck (cf. Swarth, 1931, p. 181) reported finding a nest of *debilirostris*, but no specimen was obtained. However, in the Stanford Collection there are two black males labeled *fuliginosa* which seem rather too large for this species and they have straight culmens. They may consequently be referable to a form of *difficilis* (*sensu stricto*) of Tower and Abingdon islands than they do *debilirostris* of James and Indefatigable. Additional specimens are needed in order to settle this point.

During our stay on Indefatigable we found no *Geospiza debilirostris*. Either we overlooked it or it had disappeared. Swarth (MS) saw quite a number in 1932. At the same locality, Fortuna, he recorded *Nesomimus* as being extremely abundant. In 1939, we found the latter to be extremely scarce there near human habitations. Conceivably the clearing of the forest and other human activities of recent years have indirectly caused the disappearance of *Geospiza debilirostris* and the decrease of *Nesomimus*.

One specimen of *G. fuliginosa* from James Island (Rothschild

Collection, No. 517369) has the straight culmen characteristic of *difficilis*; so also has a black male (Stanford Collection, No. 5251) and a female (University of Michigan, No. 88889) from Abingdon; but all these specimens are typical of *fuliginosa* in measurements, so have been assigned to this species. They are much too small for *difficilis*, but could conceivably be dwarf *difficilis* or of hybrid origin. Some Chatham Island specimens of *fuliginosa* have nearly straight culmens, and, since they also approach *difficilis* from Tower Island in size, might be difficult to distinguish if they occurred on the same island.

A black male from James Island (Rothschild Collection, No. 517702) seems intermediate between *Geospiza fortis* and *G. d. debilirostris*, so that I cannot positively assign it.

### *Geospiza nebulosa* Gould

The type of this species in the British Museum (No. 37.2.21.400) was collected by Darwin; hence its locality is uncertain, and there is no real evidence that it came from either Chatham or Charles Island, as was once thought. No later specimens have ever been assigned to this form, but another of Darwin's specimens (No. 55.12.19.20) labeled "*Cactornis scandens*" seems to me to belong here, as it is extremely similar in size and shape of bill, wing length, and probably in color if allowance is made for fading. Swarth placed this second specimen with "*Cactornis assimilis*" (see *Geospiza scandens*), and synonymized the type of *nebulosa* with *fortis*. I cannot agree with either of these conclusions. The specimens seem to me to fall in the *difficilis* group, agreeing particularly in the shape of the bill, including the almost straight culmen. Their dimensions, however, particularly as regards depth of bill, are too large for them to be assigned to any of the present forms of *difficilis*, and they also lack chestnut on the wing bar and undertail coverts. Either, as with *Geospiza magnirostris*, measurable evolution has occurred since the time of Darwin's visit, or they represent an extinct form of *difficilis* from Charles or Chatham Island, where this species is unknown today. Darwin's collection also includes a typical specimen of *debilirostris* (originally labeled *Geospiza strenua*) which probably came from James Island, an occurrence which favors the second suggestion, although the first is not ruled out.

If I am correct in relating *G. nebulosa* to the *difficilis* group,

then there is necessity for replacing the latter by the former as the specific name of the group. This seems inadvisable, however, since *nebulosa* is represented by only two specimens, and further is now extinct, so that its affinities cannot certainly be known.

### **Geospiza scandens superspecies**

Plate 3, figures 1, 2, and 3

Swarth recognized the following forms of *Geospiza scandens* (Gould): *abingdoni* (Sclater and Salvin) of Abingdon Island, *rothschildi* (Heller and Snodgrass) of Bindloe Island, *scandens* (Gould) of James Island, and *intermedia* Ridgway of Indefatigable, Duncan, Albemarle, Barrington, Chatham, and Charles islands. These names are correlated with measurable differences in general size and size of bill, but, as Swarth states, the differences are so slight that all the birds might be placed under one name. The latter procedure is adopted here, since in most cases less than 75 per cent of the specimens can be identified with certainty. The specimens from James Island can be separated readily from those from Bindloe Island, and there is almost no overlapping, hence they should bear separate names. However, the birds from Abingdon, Jervis, Indefatigable, etc., bridge the gap between the two. This would present no difficulties if James and Bindloe were at the two ends of a chain of linked forms, but this is not the case. James and Bindloe are adjacent islands, and the intermediate forms occur both to the north and to the south of them, making any consistent nomenclatorial treatment impossible. Under the circumstances, I consider it more practical not to use subspecific names, but to refer to the species followed by the name of the island, as adopted in other species where there is much overlapping between island forms. This procedure was adopted by Mayr (1932*a*, pp. 5-10) for *Foulehaio c. carunculata* which presents similar difficulties.

As noted by Swarth (1931, p. 200), Chatham Island specimens of *G. scandens* tend to be shorter-billed than other "*intermedia*," and, if the latter name is retained, the Chatham birds might be considered as a separate form. Incidentally, their scarcity in collections is because the plant *Opuntia*, to which *scandens* is closely restricted, does not occur where the collectors have worked on Chatham Island. We found the birds common locally, and not too easy to distinguish in the field from *fortis*; a difficulty not experienced with the longer-billed *scandens* of Indefatigable Island.

The three specimens assigned to the *scandens* group collected on the voyage of the "Beagle" and now in the British Museum are the type, a black male with so small a bill that it almost certainly came from James, the specimen which I have assigned to *Geospiza nebulosa*, and the type of *Cactornis assimilis* Gould. Swarth could not safely assign the last to any present form of *scandens*, but stated that it came nearest to Bindloe Island specimens, with which judgment I agree.

There are three puzzling specimens, two in the Rothschild Collection (Nos. 517703, 517815) and one in the British Museum (No. 99.9.-1.358), two from James Island and one from Chatham Island, all in immature plumage. All were labeled *scandens* but their bills are so small that I at one time thought they were *debilirostris*. This was wrong, as indicated both by their coloration and the proportions of their bills. I am not yet altogether satisfied that they are immatures of *scandens*, although this seems to be the most probable conclusion.

Also placed in the *scandens* superspecies are *Geospiza c. conirostris* Ridgway of Hood Island, *G. c. propinqua* Ridgway of Tower Island, and *G. c. darwini* Rothschild and Hartert of Culpepper Island (for the last, see note under *G. magnirostris*). The female plumage, the relatively less deep bill as compared with other *conirostris*, and the song, show clearly that *propinqua* is closely related to *scandens*. In *conirostris*, the females are typically much darker than in *propinqua*, but simply carry further the tendency found in the *scandens* group. The song is distinctive. The bill of the immature is not deep and shows a clear resemblance to that of *scandens*. The plumage of *darwini* is somewhat distinctive but shows resemblances to that of *propinqua*, while the bill is of the *conirostris* type. The writer agrees with Swarth in relating *conirostris* to *scandens*, which it replaces geographically. Stresemann (1936) suggested that *conirostris* was related to *fortis*. One specimen of *conirostris* from Gardner Island near Charles Island in the Rothschild Collection was doubtless a straggler (see Rothschild and Hartert, 1899, p. 159).

### **Platypiza crassirostris (Gould)**

Plate 3, figure 4

Not separated into island forms. The type specimen has disappeared. The British Museum specimen, incorrectly listed by

Sharpe as the type (cf. Swarth, 1931, p. 209), is typical of *Camarhynchus psittacula* and Swarth suggests that it is an aberrant example of *psittacula*.

### **Camarhynchus psittacula** superspecies

Plate 4, figures 1 and 2

This includes *Camarhynchus psittacula* Gould of James, Indefatigable, Barrington, and Charles islands, *C. habeli* Sclater and Salvin of Abingdon and Bindloe islands, *C. affinis* Ridgway of Albemarle Island, and *C. pauper* Ridgway of Charles Island. Ridgway separated the form of *psittacula* on Charles Island as *Camarhynchus townsendi*, but Swarth provisionally synonymized the latter with the former, with which I fully agree as their measurements widely overlap. Both *psittacula* and *pauper*, two species of the same superspecies, occur on Charles Island, as is later discussed in detail.

Two specimens of *psittacula* from Chatham Island in the Rothschild Collection were presumably stragglers. Gifford (1919) reported seeing this bird on Chatham. We saw none there.

Some puzzling specimens from James, Jervis, Indefatigable, and Seymour islands were described by Ridgway as *Camarhynchus incertus*. Swarth referred them to *affinis*. In bill and plumage, they resemble *affinis*, not *psittacula*. Possibly all are stragglers of *affinis* from Albemarle Island, but there are so many that *affinis* is perhaps establishing itself on these islands. Alternatively, *psittacula* may be more variable than supposed. It is possible that *Camarhynchus psittacula* and *C. affinis* meet on Duncan Island. Further collecting is much needed.

The species here grouped with *psittacula* might better be classified as subspecies of one species, but it seems inadvisable to make any alteration until the problem concerning *affinis* has been cleared up.

### **Camarhynchus parvulus** (Gould)

Plate 4, figure 3

*Camarhynchus parvulus salvini* Ridgway of Chatham Island is larger than the typical race. Two specimens of *C. p. parvulus* from Wenman Island, and three from Abingdon, all in the California Academy of Sciences, were perhaps stragglers, but at least on Abingdon they may well be resident.



INTERMEDIATES BETWEEN *Camarhynchus psittacula*  
superspecies AND *Camarhynchus parvulus*

Eight specimens from south Albemarle Island, six in the collection of the California Academy of Sciences (cf. Swarth, 1931, p. 232) and two at Stanford, seem intermediate between *Camarhynchus affinis* and *C. parvulus*, while two specimens from Charles are intermediate between *pauper* and *parvulus*. They might be abnormal specimens of either species, or hybrids.

*Cactospiza pallida* (Sclater and Salvin)

Plate 4, figure 4

Swarth recognized the following races: *pallida* on James, Indefatigable, and Duncan islands, *producta* (Ridgway) on Albemarle, and *striatipecta* Swarth on Chatham. James Island specimens are gray, Indefatigable specimens olive, perhaps enough to justify revival of the name *hypoleuca* (Ridgway) for the James Island birds; but the Albemarle specimens present difficulties. *Cactospiza p. producta* was separated from *C. pallida* by its smaller bill, but their measurements overlap too much to justify this. North Albemarle birds are gray, like *pallida* on James Island, while south Albemarle specimens are olivaceous, like those on Indefatigable. Only two races of *pallida* are admitted here, *pallida* and *striatipecta*.

One specimen (California Academy of Sciences Collection) from Charles Island is perhaps a straggler.

*Cactospiza heliobates* (Snodgrass and Heller)

Restricted to the mangrove belt on Albemarle and Narborough islands.

*Certhidea olivacea* superspecies

Plate 4, figure 5

This form was divided by Swarth into island species which, as he states, might equally have been called subspecies, as was done by Hellmayr (1938, pp. 142-145), and is followed here. The races of *C. olivacea* Gould are: *becki* Rothschild of Culpepper and Wenman islands, *fusca* Sclater and Salvin of Abingdon and Bindloe islands, *mentalis* Ridgway of Tower Island, *olivacea* of James, Indefatigable, Albemarle, and Duncan islands, *bifasciata* Ridgway

of Barrington Island, *luteola* Ridgway of Chatham Island, *cinerascens* Ridgway of Hood Island, and *ridgwayi* Rothschild and Hartert of Charles Island.

The Abingdon and Bindloe Island birds differ in wing length, but not sufficiently to justify separation. *Certhidea olivacea* on James, Indefatigable, and Albemarle islands differ almost as much from each other as do some of the forms separated by Swarth, so, as the latter states, the names *salvini* Ridgway and *albemarleii* Ridgway might possibly be revived for the birds on Indefatigable and Albemarle islands, respectively.

### **Pinaroloxias inornata (Gould)**

Plate 4, figure 6

Found on Cocos Island. In bill and food habits, it comes closest to *Certhidea*, in plumage to *Geospiza difficilis septentrionalis*.

### **SWARTH'S NEW SPECIES**

The two specimens of *Camarhynchus conjunctus* from Charles Island, the one *Camarhynchus aureus* from Chatham Island, and the one *Cactospiza giffordi* from Indefatigable Island, all described by Swarth, are, in my opinion, merely variants, not valid species. The first and second seem intermediate between *Camarhynchus* and *Certhidea*, the third is either a diminutive *Cactospiza*, but with buff on the upper breast, or is intermediate between *Cactospiza* and *Certhidea*. While their characters suggest hybridization, field observations make this seem unlikely, for the different genera are quite different in their habits, and hybridization between genera usually occurs only in birds which form an indefinite pair-bond. Hence their position is uncertain.

On Indefatigable Island, the writer saw a bird identical with *Cactospiza pallida* in plumage, habits, and call notes, but similar in size to *Cactospiza giffordi*, although lacking the buff throat patch. Possibly it could be referred to *giffordi*.

## SECTION II. BREEDING BEHAVIOR

Detailed studies of breeding behavior of the following nine species were made by W. H. Thompson and the writer: *Geospiza magnirostris*, *fortis*, *fuliginosa*, *scandens*; *Platyspiza crassirostris*; *Camarhynchus psittacula*, *parvulus*; *Cactospiza pallida*; and *Certhidea olivacea*. Each of us tended to concentrate on certain species, but each of us worked on all species at least sufficiently to check on the other's main findings. In what follows, all species are treated together as their behavior patterns are extremely similar excepting where otherwise indicated.

The Geospizinae are so indifferent to human presence that they can usually be observed from a distance of from ten to twenty yards without causing any disturbance. Owing to the variability in plumage, bill, color, and song, it was often possible to recognize individual birds, hence, to make day to day studies of them. The early stages of the breeding behavior were worked out chiefly in the intermediate forest of Chatham, where breeding was just starting on our arrival. At this time observation was facilitated because the trees were not yet in leaf. Apart from the general problem of speciation in the Geospizinae, the observations are of interest in that they contribute additional information on the life histories of tropical birds.

### PAIR-FORMATION

The breeding cycle follows a typical territorial passerine pattern. Outside of the breeding season many of the birds, if not all, are in flocks. Shortly before the beginning of the heavy rains in December or January, the mature birds begin to leave the flocks. In many cases, an unmated male was seen defending a territory, some days later acquiring a mate, which later nested with it in the territory. This seemed the normal method of pair-formation. In a few cases, the newly formed pair disappeared, and on several occasions members of a pair were seen to arrive together, the male claiming territory. Shift of territory shortly after pair-formation is not rare in other territorial birds. The possibilities of some pair-formation in the non-breeding flocks, and some birds remaining paired during the non-breeding season, are not excluded, particularly in *Platyspiza crassirostris*, where no flocks were seen (Gifford,

1919, also notes this). Wandering pairs of *P. crassirostris* were common at the beginning of the breeding season, and an occasional wandering pair of *Geospiza fortis* was also seen.

When a *fortis* or *fuliginosa* in female plumage enters the territory of an unmated male, it is sometimes chased out, but may also elicit a sexual reaction. Hence the unmated male probably is able to distinguish potential mates from other birds, including males in immature plumage, which were indistinguishable to us. However, the factors involved are unknown.

As in warblers and buntings (Howard, 1929), but not in the British robin (Lack, 1939), the interval between pair-formation and laying, which may last a few days or at least a month, is occupied by much courtship of the types described later.

#### TERRITORY-AGGRESSIVE BEHAVIOR

Each male or pair has a territory. As with most territorial passerine birds, it is usually impossible for a man to drive out the male in possession of the territory. As the observer approaches, the bird retreats, but when it reaches the edge of its territory it will not retreat farther, and eventually flies back past the observer into the center of the territory. The boundaries of territories were sharply defined where the birds came in contact with neighboring males. Here both males displayed aggressively at each other, and often each owner flew along his boundary with slow, descending, round-winged flight, singing hard.

In all species except *Certhidea*, the male bird normally drove out vigorously all intruding individuals of its own species of both sexes. In *Certhidea*, the male normally drove out only trespassing males, the defending male showing excited movements but rarely attacking a strange female. The reason for this difference is not known. The females of *Geospiza* vigorously drove out other females, but never attacked intruding males in black plumage. In two instances, the strange intruding male even went up to the nest without the owning female attacking. Males in immature plumage were thought to be abundant, but were indistinguishable to the observer from females, and probably to the female *Geospiza* too, since the latter drove out all birds in female plumage. When a male *fortis*, which was mostly in streaked plumage but showed partial black feathering, trespassed, the occupying female *fortis* started to attack it, but the male resisted instead of retreating, and the

female then desisted and fed quietly near it. The female's mate *shortly came up and drove the other male away*. In a second case, after showing some aggressive behavior toward the strange male, the female actually received food from it as in courtship. In a third instance, the intruding male, in the absence of the owner, proceeded to visit the nest and display to the female, who did nothing.

Females of *Platyspiza*, *Camarhynchus*, and *Cactospiza* possibly behave like those of *Geospiza*, since they were seen attacking intruders of their own species in female plumage but did not attack distinctively plumaged male intruders. However, owing to the scarcity of distinctively plumaged males on Chatham, where most observations were made, the data are not really sufficient. One female *Platyspiza* chased a black male *Geospiza fortis* from her nest. The female *Certhidea* did not usually show aggressive behavior toward intruders of either sex, but apparently chased them rarely.

Away from the center of the territory, intruders of either sex feeding on the ground are sometimes tolerated in their territory by members of the established pair, which may even feed with them. This was noted once in *Cactospiza pallida* and several times in *Geospiza fortis* and in *G. fuliginosa*. Two incidents are of special interest. Near the edge of, but definitely inside of its own territory, a pair of *fortis* was feeding on the ground together with a strange *fortis* in female plumage. After some minutes, the pair flew to the center of the territory, and a moment later the intruder followed the pair (a social response) and was promptly driven out. On another occasion, a male *fuliginosa* was feeding on the ground ten yards inside the territory of the neighboring male, which fed peaceably beside it. After an interval, the intruder stopped feeding and flew to a piece of lichen on a bush six feet off the ground. The owner promptly attacked and drove it out, singing loudly, and when it attempted to return drove it out again. The significance of lichen clumps in nest display is discussed later. By its action, the intruding male became a sexual rival instead of a food companion. A parallel case involving song-posts is described for *Anthus pratensis* by Venables (1937, p. 77).

Most territorial birds keep a strict lookout for intruders. This was not the case in the Geospizinae. Especially in *Geospiza fortis*, *G. fuliginosa*, and *Camarhynchus parvulus*, intruding males were sometimes in the territory for several minutes, and might even have

visited several display nests, before they were detected by the defending male, who might have been only ten yards away, but looking in another direction.

When an intruder was seen, the defending male normally flew to it, at which the intruder usually flew off and was pursued out of the territory. If the intruder did not retreat, the owner normally flew around to perch directly in front of it, and if it still did not retreat, gripped its beak. The intruder soon retired. Song and threat postures also were used in attack, particularly between full-plumaged males, and especially between neighboring males on the edges of their territories. These remarks apply to all except *Certhidea*. When the occupying male saw an intruder in the territory, it usually uttered a special part of its song. An intruding male usually gave the same phrase in reply, at which the owner promptly attacked and drove it out. Silent birds, usually females, were sometimes, but not often, attacked. In *Certhidea*, too, the fights, particularly between neighboring males, were apt to be fiercer, and the birds not infrequently fell interlocked to the ground, pecking hard.

The male normally confined his singing, attacking, and nest-building to his own territory. The pair did much of its feeding inside the territory, but also considerable outside of it. Sex-chases, male pursuing female, often took the members of the pair far outside of their own territory. These sex-chasing intruders particularly excited territorial owners.

#### FUNCTIONS OF SONG

Male song serves the same functions as in other territorial species, that is advertisement to females and to neighboring males. It is loud in the unmated male, also in newly paired males. It declines conspicuously during incubation. It is especially loud during and just after attacks on intruders and sometimes when the male displays to the female. The song is delivered from perches in the territory, also, in all except *Certhidea*, during a special flight, slower with more rounded wings, usually descending from a higher branch to a lower. This song-flight is also common when going to or from the nest during display-building. In *Cactospiza pallida*, as in the other species, the song-flight is normally from one branch to another below the canopy of the forest trees. However, where this species occurs in the six- to ten-foot scrub in the higher hills,

the same movements result in an aerial song-flight above the low trees, which makes the bird conspicuous for a long distance.

#### POSTURES—SECONDARY SEXUAL CHARACTERS

The postures of the *Geospizinae* are often vigorous and excited but, like their songs, are unspecialized. Sometimes the wings were fully expanded and held out, the bird at times turning from one side to the other in this position, which occasionally involved turning its back on the bird to which it was posturing. Sometimes the expanded wings were vibrated slowly up and down. Sometimes the wings were only partially expanded, somewhat lowered and quivered rapidly. Sometimes the tail was spread laterally but not erected. These postures were extremely similar in all the species, excepting that in *Certhidea* wing-quivering was normal, but full expansion with the motionless wings was seen only once. Loud song frequently accompanied the posturing.

This posturing was used equally in aggressive behavior against intruders and in sexual behavior between the members of the pair. The sexes had similar postures, although males postured much more often than females. Usually birds have different attitudes for aggressive and sexual behavior, but this is not the case in the *Geospizinae*. Furthermore, fledglings begging food from adults used the same posture with quivering, dropped wings or with wings fully expanded and moved up and down.

The postures exhibit no special plumage markings. The only striking color on the otherwise black male is seen on the under-tail coverts which are tipped with whitish. These are not displayed. When feeding on the ground, birds of both sexes are apt to spread and elevate the tail, which in the male reveals the under-tail coverts. The color of these coverts either was acquired incidentally, or would seem to have lost any function which it once possessed.

The males of some forms of *Certhidea olivacea* show an orange patch on the throat and breast. The normal postures do not specially display the breast, but twice we saw a male stretch its breast somewhat when another species came to its nest. At least in *C. o. olivacea* of Indefatigable and *C. o. luteola* of Chatham, the orange patch seems to have no function today.

Males of *Geospiza* frequently breed in immature plumage, or in partially adult plumage. The behavior and postures of such individuals seemed identical with those of males in full plumage.

The same applied to males of *Platyspiza*, *Camarhynchus*, and *Cactospiza*, in which breeding in immature plumage is progressively more regular.

### NEST-BUILDING

In the Geospizinae, nest-building is closely linked with display, as occurs in some other birds which do not have enemies at the nest, as, for instance, the herons. The male often starts several nests, usually based on the remains of old ones from the previous year, which are to be seen everywhere in the forest. Early in the breeding season, building is sporadic, the male may pick up material then drop it and do something else, or may visit several nests one after the other. The male frequently sings when building. Nest-visiting and -building are greatly stimulated by the presence of a female, and their part in pair-formation was particularly well shown when a female *Cactospiza pallida* settled on the boundary between the territories of two unmated males. Both promptly sang violently, displayed, and made building movements at lichen tufts. The female left shortly. Many similar incidents were noted.

When the female is near, the male may enter one nest after another, often singing and posturing in the entrance or going in and out as if to persuade her to enter. If the male does not yet have a nest of his own, he will often visit the nest of another species of Geospizinae. For example, a displaying male *Camarhynchus parvulus* entered the nest where a female *Cactospiza pallida* was incubating and was chased out. A male *Certhidea* was often seen to visit the nest of a *Geospiza fortis*, or the reverse; the smaller species offered no resistance; the larger, if present at the time, chased away the intruder. Many similar happenings have been recorded in all the other species. During two days' observation, one courting male *Geospiza fuliginosa* was seen to visit eight nests regularly, some of which were also visited by four other species, namely *G. fortis*, *Platyspiza crassirostris*, *Camarhynchus parvulus*, and *Certhidea*. When no nest of any kind is present in the territory, the male frequently visits lichen tufts, the most common nest material, and acts as if these were a nest; occasionally clumps of other vegetation have served, and in one case a strip of linen on a bush.

The male frequently deserts the first nests. In later stages, the female takes part in building, and sometimes has been seen to build alternately in two of the male's display nests. However, the pair



soon concentrates on one nest. Even then they might desert and start yet another nest, or more usually take over the partially built and deserted nest of another species. In some instances, the whole of the nest eventually used for breeding was built by the female.

### SEXUAL FLIGHTS

As in the warblers and huntings (Howard, 1929), sexual flights are a prominent feature of courtship. The male pursues the female, often singing, and sometimes carrying building material. The wings may be spread so that they appear broader than usual. The writer agrees with Howard in interpreting these flights as incipient attempts of the male to copulate, the female taking flight before the male reaches her. This does not mean, however, as Howard implies, that the male is necessarily able to copulate. Initiatory movements, sometimes called symbolic, are frequent in the courtship of many birds and sexual flights come in this category. In one case, the male was clearly ready to sex-chase but not to copulate, for when a female *maguirostris* invited the male to copulate he did not respond; the female then flew off and the male promptly commenced sex-chasing. Not infrequently, sex-chases were initiated by the female. The sexual posture of the stationary male with fluttering wings may be regarded as an initiatory movement of sexual flight.

### COPULATION

Copulation is normally initiated by the female assuming a position similar to that of many other passerine birds, motionless with bill sometimes pointing upward. A similar posture with bill upward was occasionally seen in the courting male. On two occasions, a male *Certhidea* attempted to mount a female which had not assumed the invitation posture, once when the female was temporarily entangled in lichen.

### COURTSHIP FEEDING

As in many other species, the male feeds the female not only during incubation but also throughout courtship. In all species the food was first swallowed by the male, and then, almost immediately afterward, regurgitated to the female, often with much saliva. In *Geospiza*, berries and more rarely caterpillars were the chief food passed. In *Certhidea* and *Cactospiza*, insects were primarily used.

In one instance, a male and female *Platyspiza crassirostris* were seen to pass the same caterpillar from one to the other several times, but such an exchange was not otherwise observed. Often early in the breeding season no food was passed; the birds simply touched bills. Such billing is another example of an initiatory movement in courtship behavior.

Normally the courtship feeding had no connection with other courtship, but in one instance a male *Camarhynchus parvulus* fed the female while copulating (W. H. Thompson). Conceivably the vertical bill of the female in the copulatory attitude is a relic of a former feeding habit which has now almost disappeared in the behavior of the Geospizinae. For a general discussion of courtship feeding, see Lack (1940a).

#### ORDER OF BREEDING CYCLE

In the buntings, Howard (1929, pp. 1-27) described a definite sequence of breeding behavior. In the Geospizinae, some of the phases are variable in their order of occurrence. For instance, one male claimed a territory with song but had no mate and no nest interest, while a neighboring unmated male was building rapidly. Another male already had a mate, but neither sex showed any interest in building. Again, in some cases courtship feeding was seen within an hour or two of the formation of the pair, in another instance it was not observed before incubation started.

#### INCUBATION AND FEEDING OF THE YOUNG

Incubation was studied but slightly because almost all of the nests were out of reach. For all the species observed, four was the usual number of eggs; one pair of *fuliginosa* reared five young. In one *magnirostris* nest, the first, second, and third eggs were laid on consecutive days, while the time of laying of the fourth was not recorded. The young hatched, one on the 14th, one on the 15th, and two on the 16th days after the laying of the first egg, and they left the nest twelve days after the last one hatched. The female occasionally brooded the young for five days after the first young hatched.

Only the female incubates. At intervals the male appears, calls her off the nest and feeds her. When some young *magnirostris* were newly hatched, the male not infrequently fed the female on the nest itself, but this was not observed during incubation. The

female tended not to incubate during the heat of the day. The temperature of the eggs inside the nest was taken on two occasions: at 2:00 P.M. sun-time when the air temperature was 84° F. the eggs were at 98° F.; on the following day half an hour after noon with the air at 83° F. the eggs were at 96.5° F. In neither instance had the female been incubating for several hours. Clearly she had little need to.

Both sexes feed the young in the nest. In all birds observed, the female fed the young more frequently than the male, coming approximately every 20 minutes with food during the early morning and evening, at greater intervals during the heat of the day, while the male came every 30 or 40 minutes. During the first day or two, the male sometimes fed the female, who then fed the young.

Feeding was by regurgitation. The food for the young in *magnirostris*, *fortis*, and *fuliginosa* consisted primarily of sphingid caterpillars, at that time extremely common in the coastal zone, and also berries. In the higher parts of the intermediate zone caterpillars were scarce and berries were the main diet. These would seem to provide inadequate nutrition for the young, but much saliva passed with them, and this perhaps contained nutriment. *Certhidea* fed its young primarily on small insects.

Once the young leave the nest they are fed exclusively by the male. When two out of four young *magnirostris* had left a nest the female merely seemed bewildered by the food-begging of these two perched close to the nest, and she fed only the two inside. The posture of the young begging for food is with fluttering and expanded wings like that of courtship display. As soon as the fledglings leave the nest, they tend to posture at any moving bird, including any species of Geospizinae which happens to come near. Young *fuliginosa* have been seen to posture at an adult *magnirostris*, also vice versa, and young *scandens* have been seen to posture at both. Evidently the external stimulus which releases food-begging is a simple one. The main factor in the parents' location of the young is therefore supplied by the latter, probably correlated with the complete absence of enemies; the fledglings are much more conspicuous in their behavior than European passerine birds could afford to be.

The female disappears when the young leave the nest. During the preceding few days there is sometimes a resumption of sexual activities between the members of the pair, chiefly sex-chasing and

rarely copulation. It is, therefore, possible that the female goes off and starts a new brood, but since she always moved immediately away from the first brood this was not determined. Beebe (1924, pp. 260-261) recorded two parents feeding a fledgling and at the same time frequenting a nest with one egg, but this observation does not fit into the breeding pattern as observed by us.

#### NATURE OF ADULT SONGS

The songs of all of the species are of primitive pattern, unmusical, with no complex phrases. The tone of the larger species, at its best, approaches that of *Agelaius* and *Xanthocephalus*, two North American icterids.

Omitting *Certhidea* and *Platyspiza*, the typical songs of every species could be represented by some such words as "tchur tchur tchur tchur" (monosyllabic type) or "tchur-wee tchur-wee tchur-wee" (disyllabic type). In addition, other phrasings occur in all of the species, such as: "tchur-lee-tee-tee," "tee-chur," and others. The phrases and number of notes, that is the "pattern" of the song, being so variable, the chief differences between the various species lie in the quality, and to a less extent in the time intervals between the notes. Hence, any attempt to describe the differences by means of human syllables breaks down hopelessly. With practice, it is possible for a field observer to identify correctly most of the adult songs heard, as indicated below:

*Geospiza magnirostris*.—Of a slower tempo than that of other forms of *Geospiza* and more melodious and forceful. Some individuals were indistinguishable from *fortis* or *scandens*. Those on Tower Island seemed indistinguishable from those on Indefatigable.

*Geospiza fortis*.—A generalized type of song, usually harsh, occasionally more melodious and usually stronger than in *fuliginosa*. Some individuals were indistinguishable from *magnirostris*, *fuliginosa*, *scandens*, and occasionally from *Cactospiza*, and one came extremely close to *Platyspiza*.

*Geospiza fuliginosa*.—Typically like *fortis*, but weaker. This is the most generalized song of all the *Geospizinae*. While many individuals were distinguishable, some were not separable from *fortis*, *scandens*, or *Camarhynchus parvulus*. A disyllabic form of song was more common than the monosyllabic.

*Geospiza difficilis difficilis*.—Although this species so closely resembles *fuliginosa* in appearance, its song is distinctive, consist-

ing of short and more feeble notes, often with a hissing note in the middle, so that in timbre it approaches the song of *Certhidea*.

*Geospiza difficilis debilirostris*.—(Not heard by us) Swarth (MS) states that the song is very distinct "like a tiny siren running down."

*Geospiza scandens*.—Typically a rapid succession of notes. In tone quality usually intermediate between *fortis* and *fuliginosa*, often, but by no means always, with more syllables in each phrase. Usually all syllables were of the same quality, but a "disyllabic" type also occurred. Some individuals were indistinguishable from *magnirostris*, *fortis*, *fuliginosa*, and *Cactospiza*.

*Geospiza conirostris propinqua*.—The few individuals heard had a song consisting of a rapid succession of notes, indistinguishable from the song of *scandens* on Indefatigable.

*Geospiza conirostris conirostris*.—Rather distinctive song, usually fairly musical. Some individuals were perhaps indistinguishable from *fortis*, *scandens*, and *Platyspiza crassirostris*.

*Platyspiza crassirostris*.—More distinctive than most. Several rather musical notes run into a grinding "churr," this phrasing being remarkably constant and specific although in quality it varies slightly, particularly the vigor of the "churr." As in other species, a "hiss" is sometimes added to the song phrase.

*Camarhynchus psittacula*.—Two main types of song, one soft, rather slow, disyllabic, and the second, a rapidly repeated succession of harsh notes, similar to *Cactospiza* but less strong. A typical "churr" and a high-pitched, rapid succession of "see" notes are often added to the song phrase.

*Camarhynchus parvulus*.—Two main types of song, one a rapidly repeated succession of similar harsh notes, the second, various combinations of two types of harsh notes succeeding each other rapidly, the phrasing and accenting being extremely variable. Some types were reminiscent of one call of the great tit (*Parus major*). The second type is usually harsher and shorter than the disyllabic type in *Camarhynchus psittacula*, but musical varieties occur. A "churr" and a long-drawn "sec" may be added to the song, but less commonly than in *psittacula* or *Cactospiza pallida*. Some individuals have been confused with *psittacula* or *Geospiza fuliginosa*. Near the summit of Indefatigable nearly all the *parvulus* had musical songs, whereas in the intermediate zone they were normally harsher.

*Cactospiza pallida*.—A rapid succession usually of seven to eight notes, often more, with either all of one type or of two. Typically loud, and usually more musical than in other species, but harsher in some individuals. Phrasing and tone were extremely variable. A “churi” and long-drawn “see” were joined with the song much more frequently than in other species. Occasional individuals have been confused with *Geospiza fortis*, *G. scandens*, *Camarhynchus psittacula*, and, in pattern but not in volume, with *Camarhynchus parvulus* and *Certhidea*.

*Certhidea olivacea*.—A rapid succession of notes thinner than any other *Geospizinae* except *Geospiza d. difficilis* from Tower Island. In *Certhidea olivacea luteola* of Chatham Island, the main song is reminiscent of the European wren (*Troglodytes troglodytes*). In *Certhidea olivacea* on Indefatigable, there were typically far fewer notes in the phrase, which was a little louder and more harsh than in the Chatham birds, being not unlike the song of *parvulus*. One rapidly repeated succession of notes was common to the song in both islands.

#### SONG DIFFERENCES AND EVOLUTION

As might be expected, the songs of the different genera are more distinctive than are those of closely related species, but even here considerable overlapping occurs. Points of special interest (see later discussions) are: the song of *Geospiza conirostris propinqua* seems indistinguishable from that of *G. scandens* of Indefatigable, one of several links between these forms. The song of *G. c. conirostris* is typically more differentiated, and bears no particular resemblance to that of *scandens* or *propinqua*. The song of *G. d. difficilis* from Tower Island is quite distinct from that of *fuliginosa*, a species which it resembles greatly in appearance, and from which it probably was evolved. *Platypiza crassirostris* has the most specialized and constant song of any form, with no particular resemblance to the song of *Camarhynchus*, the genus in which it was usually placed until Ridgway and Swarth erected a new genus for it. *Cactospiza pallida* was formerly classified with *Geospiza scandens*, owing to their superficially similar bills. From its plumage, Swarth and others placed it next to *Camarhynchus*, and its song, as well as its feeding habits, strongly support this. In *Certhidea* the song is, like all its characters, more distinctive than that of the other *Geospizinae*, but shows obvious *geospizid* affinities. In general, if

song could be more objectively recorded, it might be a valuable guide to classification.

The function of most bird song is advertisement by the unmated male to females in search of mates, and to rival males. The songs of closely related species are normally distinctive, which facilitates the female in finding a mate of her own species. The overlapping between the songs of the different species of *Geospizinae* is highly unusual among birds. Of special significance is the fact that the patterns of the songs overlap, the differences being mainly in quality, and very possibly non-adaptive. Song may not be of fundamental importance in keeping these species apart, although the possibility remains that, while the songs overlap to human ears, the birds detect differences. However, in a wide experience with European and other birds neither W. H. Thompson nor the writer have experienced similar difficulties in identification.

#### JUVENILE SONG

Juvenile song occurs in all species. It is sometimes like adult song, but tends to be more variable and so is less easily identified. Often "churr," "hiss," "zip" and other odd notes are introduced, the whole being roughly strung together and often uttered quietly, almost "conversationally" and directed at no special object. This song is frequently heard from males in streaked and partially streaked plumage while still in the non-breeding flocks, and has been heard from young which could not have been out of the nest for more than a month. Also some streaked male *fortis* acquiring their territories have begun with such song but much louder, gradually changing to an adult song in the course of several days.

#### CALL NOTES

The calls of all the species are, like their songs, simple and generalized. A note which might be written "tchra" in some species, varying toward "keu" in others, is used in aggressive, sexual, and social behavior. The female sometimes repeats this note rapidly and in a higher pitch, especially under sexual excitement. W. H. Thompson describes a female "song" in *Cactospiza pallida*, but if we heard the same note, the writer considers that it was simply this excited call. All species also have a "hiss" and various clicking notes. The "hiss" is heard in *fortis* and *fuliginosa* particularly when the pair meet at the nest.

In *Certhidea*, the songs and calls seem of greater importance than in the other species. The pair constantly keeps in touch by calling, and an intruding male is also recognized by his voice.

#### ATTACKS ON ALIEN SPECIES

All of the species watched were, at times, seen to attack individuals of most of the other species of Geospizinae. Occasionally aggressive individuals also attacked mockingbirds (*Nesomimus*), warblers (*Dendroica petechia*), and flycatchers (*Myiarchus magnirostris*). As in other territorial birds, attacks on alien species were usually sporadic and rarely continued for long.

Although aggressive behavior was often directed at other species, this was not observed for sexual behavior except that a mated female *fortis* once followed a singing unmated male *fuliginosa*, and the female's mate, who was near by, ignored this.

#### SPECIES RECOGNITION

Frequently, upon seeing an individual of a strange species enter its territory, the male would fly down as if to attack, coming around in front as if to grip its bill, and then the whole behavior would collapse. This was observed in *Geospiza magnirostris* against *G. fortis*; in *fortis* against *fuliginosa* and *Cactospiza*; in *fuliginosa* against *fortis*; and in *Camarhynchus psittacula* against *parrulus*. It happened so often that it seemed clear that the species recognized each other primarily by differences in the bills. It should be noted that the plumage of the species concerned is so similar that recognition from behind is difficult or impossible for the human observer. This behavior fits Tinbergen's views (1939) on the importance of first and second reactions in social encounters in birds, the first reaction released by a very general signal, the second by a more precise and specific one. The importance of specific recognition through bill difference is discussed in a later section.

#### FIELD EXPERIMENTS

A caged male and then a caged female *fortis* were placed at different times in the territories of two mated pairs and one unmated male *fortis*. The wild birds came down to the cage, showed mild interest, but soon left. A caged male and female *fuliginosa* were presented to four wild male *fuliginosa* with a similar negative result. This is in marked contrast to the behavior of the British



robin (Lack, 1939) and chaffinch (Lack, 1941) which attacked such caged specimens.

Experiments with mounted birds were more effective. Mounted specimens of a black male *fuliginosa* and of a *fuliginosa* in female plumage, a similar pair of *fortis*, and a *Camarhynchus parvulus* in female plumage were perched as naturally as possible near different *fuliginosa* nests, one mount being presented at a time. Experiments on the British robin (Lack, 1939) showed that a bird sooner or later ceases to take notice of a mounted specimen. When a second specimen is presented to a bird, its reaction tends to be less intense, irrespective of the nature of the specimen. Hence an increase in the intensity of the reaction to the second specimen can safely be correlated with the nature of the specimen but a decrease cannot. These points were borne in mind in the following experiments.

Experiments were performed on 16 male *fuliginosa*, 14 mated, two unmated, and on the 14 mated females, all building or courting birds.

*Behavior of male.*—Of 16 males presented with a black male mount, seven showed neither aggressive nor sexual behavior, appearing either to be uninterested or slightly alarmed; two showed mild excitement; seven showed marked aggressive behavior, three of which also showed sexual behavior, in two cases mild, in the third more intense. When presented next with the female mount, one showed mild aggressive behavior, three attacked vigorously, three others showed strong sexual behavior, and the other nine took no special notice. The males always attacked by pecking at the bill of the mount.

Males probably attacked male and female mounts about equally. The apparent decline in intensity of aggressive reaction to the female mounts is interpretable through the waning in the intensity of reaction with repetition, as already noted.

The three males which reacted sexually to the male mount first attacked the specimen by standing on its back; from this they passed into definite copulatory actions, but two of them quickly desisted. One of the latter flew straight from the back of the male mount to copulate with his own female, and both were subsequently uninterested in all mounts, including the female mount. The third bird, after a vigorous attack, copulated vigorously with the male mount; then when presented with the female mount it again copulated vig-

ously; presented with a female *fortis* it continued to display sexually but without copulating; presented again with a female *fuliginosa* there was an immediate increase in sexual display; presented with the male *fuliginosa* mount again, it showed no interest; presented with the female *fuliginosa*, it again displayed sexually. Hence, although this last bird copulated with a male mount, it responded sexually in a greater degree to the female mount. This point could not be tested with the other two males since they so quickly lost interest in all mounts. Of the other two males which copulated vigorously with the female mount, one had shown no interest in the male mount, the other had attacked it vigorously, but showed no sexual response.

The reaction of one male to a mounted female *fortis* has been described. The other two birds which reacted sexually to the female *fuliginosa* mount were also presented subsequently with a female *fortis*. One of these, like the bird already described, showed a mild sexual reaction, including an attempted copulation with the *fortis* mount, but this was not so intense as that delivered either before or subsequently to a mounted female *fuliginosa*. The other showed no reaction to the female *fortis* though subsequently it again reacted sexually to the female *fuliginosa* mount.

A bird whose aggressive reaction to the male mount had been strong was also tested with a mounted male *fortis* and attacked it; the same bird a moment later did not attack a live male *fortis* which perched close to the nest.

*Behavior of female.*—In nature the female does not attack black male intruders, hence it is not surprising to find that of the 14 females presented with a male mount, 13 showed no aggressive behavior, and the other delivered only two small pecks. No female attempted to court the male mount.

When presented with the female mount, five females attacked vigorously. Three of these were subsequently presented with a female *fortis* mount, at which two promptly ceased to react aggressively, although one subsequently reacted strongly to a female *fuliginosa*; the other attacked the female *fortis* and subsequently attacked the female *fuliginosa* more vigorously.

Of two birds presented with a mounted female *Camarhynchus parvulus*, one attacked quite as violently as it attacked a mount of its own species, although the same bird showed no aggressive behavior to the female *fortis* mount. The other bird showed a more

intense reaction to its own mount than to the *parvulus*. The reaction of a third individual to a mounted *parvulus* was, as in its response to a mounted female *Geospiza fuliginosa*, negative, but it is of interest since a few moments later it attacked a live *parvulus* which happened to alight near by.

*Experiments with Geospiza fortis*.—Three males were tested with rather indefinite results. One pulled at the bill of the black male *fortis* mount, probably trying to feed it, and later mounted, probably an incipient copulatory action. One of the others postured excitedly, either in aggression or in courtship; the other attacked mildly.

#### SUMMARY OF EXPERIMENTS ON *Geospiza fuliginosa* WITH MOUNTED BIRDS

1. *Variability*.—Although the mounted specimens were always placed in similar situations, various birds reacted quite differently to them. Similar individual variation occurred with the British robin (Lack, *op. cit.*).

2. *Sex discrimination*.—Too much must not be argued from experiments with mounted birds, since the situation presented is unnatural, and it seems probable that a motionless bird is an important factor in the external situation normally releasing copulatory behavior, which may help to explain the action of the male *fuliginosa* which copulated with male mounts. Some sex discrimination by plumage clearly exists, since two males which reacted sexually to the female mount showed no sexual behavior toward the male mount; also one male which showed some sexual behavior toward the male mount, showed more to the female mount. The two other males which copulated with the male mount subsequently lost interest in all mounts. In their experiments with various sexually dimorphic North American birds, Noble and Vogt (1935) found complete sex discrimination of mounted specimens except by juvenile birds. Hence sexual differences in plumage are perhaps less important in the lives of the *Geospizinae* than in most sexually dimorphic birds. It should be remembered that many males breed in plumage indistinguishable from that of the female.

3. *Species discrimination*.—Here also too much must not be expected from the experiments. Probably a foreign species would not normally give the signal for copulation. Also in two instances the wild bird's reaction toward the mount of a foreign species was

different from its behavior toward a living individual of the same species a few moments later.

The experiments, however, show that even under artificial conditions a wild *fuliginosa* does differentiate, to some extent at least, a member of its own species from *fortis*, even when this difference is reduced, for practical purposes, to a difference in bill, for the *fortis* and *fuliginosa* specimens were stuffed so that the difference in general size was small.

The critical experiments occurred with three male and two female *fuliginosa*. The three males (*a*) reacted sexually to a mounted female *fuliginosa*; (*b*) presented with a mounted female *fortis*, one did not respond, the other two reacted sexually but more mildly; (*c*) presented again with a mounted female *fuliginosa*, all three reacted sexually and more intensely than to the mounted female *fortis*, despite the fact that reactions to mounted specimens wane with repetition. The two females (*a*) vigorously attacked a mounted female *fuliginosa*; (*b*) presented with a mounted female *fortis*, one ceased to attack, the other attacked but not so strongly as before; (*c*) presented again with a mounted female *fuliginosa*, both attacked it vigorously, the second bird more vigorously than before. The example of a third female is suggestive but not conclusive. The bird vigorously attacked a mounted female *fuliginosa*; when a mounted female *fortis* was substituted it ceased to attack; after this it lost interest in all mounts.

To summarize, some sexual discrimination by plumage and some species discrimination by bill differences occurs in *Geospiza fuliginosa*, but neither is absolute, at least under the artificial conditions of the experiments.

#### BREEDING BEHAVIOR AND EVOLUTION IN THE GEOSPIZINAE

All the breeding habits of the different genera and species of Geospizinae are extremely similar. The acquiring and maintaining of territory, pair-formation, threat and sexual postures, display-building, nest-visiting, sexual flights, courtship feeding, the attitude in copulation, the position and structure of the nest, and the share of the sexes in incubation and the feeding of the young follow the same pattern. The songs and call notes are similar and are used in the same sorts of situations. This is all the more remarkable since the species of *Geospiza* are finch-like in general habits, *Cactospiza* climbs trees, and *Certhidea* is so like a warbler that it was at one

time classified with the North American warblers (Compsothlypidae). There are slight differences between some of the species, particularly *Certhidea*, while *Cactospiza* seems more excitable than some of the others. In the Geospizinae, breeding habits have been far more conservative in evolution than feeding habits, which are described later. In general, patterns of breeding behavior seem a valuable guide to bird classification, although it is not true of all bird groups that the breeding habits are more conservative than the feeding habits. The gallinaceous birds, the birds of paradise (Paradiseidae) and the Icteridae, illustrate the opposite.

The extremely generalized nature of display and song in the Geospizinae is of great interest. Perhaps correlated with this is the frequency with which male birds breed before they attain their full male plumage. It is possible that these facts are all correlated with a general decrease in the intensity of sexual selection in small island populations, but the nature of this correlation, if any, is obscure.

### SECTION III. ECOLOGY

This section is based upon detailed work on the islands of Chatham and Indefatigable by W. H. Thompson and the writer, and brief visits by the writer to Hood on January 30 and to Tower on April 3 in 1939.

#### Food

The differences between the bills of the various species of *Geospizinae* were formerly attributed to differences in diet. Snodgrass (1902, pp. 380-381) was the first to investigate this problem seriously and concluded that in the genus *Geospiza* "there is no correlation between the food and the size and shape of the bill." The only difference he found was that "birds with small bills eat only small seeds; birds with large bills eat both small and large seeds." This statement was based chiefly on a comparison of the small-billed *fuliginosa* with the larger-billed *fortis*, *magnirostris*, and *cinerostris*.

The present expedition did not make detailed stomach analyses, but instead concentrated on field observations of the food taken and especially on the manner of feeding. The results for each species are summarized, supplemented by references to Gifford (1919).

*Geospiza magnirostris*.—Mainly native fruits and berries, such as those of *Tournefortia*, *Maytenus*, *Cordia*, and *Croton*; nectar from the flowers of *Cordia lutea* and others; the staminate flowers of *Croton scouleri*; the young green leaves of trees; various seeds; large green sphingid caterpillars and occasionally other larvae. *Geospiza magnirostris* feeds both in trees and upon the ground, the latter especially outside of the breeding season. Beebe (1924, p. 266) records it as feeding on ants. Swarth (MS) records *magnirostris* digging in the sand on James Island.

*Geospiza fortis*.—Food and feeding habits similar to those of *magnirostris*; the same kinds of fruits, also the fallen fruits of manzanillo (*Hippomane mancinella*), flowers (chiefly tree flowers), leaf buds and young leaves, caterpillars, seeds, and occasional small insects. Beebe (*supra cit.*) states that ants are taken occasionally.

*Geospiza fuliginosa*.—Has the most varied diet of any of the

*Geospizinae*. Its food includes almost everything taken by *fortis* excepting the larger fruits and seeds, like those of the manzanillo. Grass seed, which is taken only occasionally by *fortis*, and not recorded in *magnirostris*, forms an extremely important item of diet. *Geospiza fuliginosa* occasionally visits the flowers of *Opuntia* which was not observed in *fortis*, and also regularly eats green buds and young leaves, other flowers, small green caterpillars, and pecks about on the ground, probably taking small seeds and insects. Beebe (*supra cit.*) records that spiders are sometimes taken by members of this species. Gifford states that the bulk of the food consists of small seeds but also records pulp of fallen *Opuntia* blossoms, leaves, introduced fruits, carrion, refuse, and marine worms taken below high-tide mark.

*Geospiza difficilis debilirostris*.—Not observed by us; said to feed on the forest floor (Gifford, *op. cit.*, p. 238).

*Geospiza difficilis septentrionalis*.—Harris (1899, pp. 89–91) and Drowne (1899, pp. 107–111) record this bird as walking about on the backs of nesting boobies (*Sula dactylatra granti* Rothschild) and picking off insects; also feeding on carrion. Gifford (*op. cit.*, pp. 241–242) records that they feed chiefly on the ground where they scratch and dig, also on leaves, cactus, and, in one instance, on the blood of a shot bird.

*Geospiza scandens*.—Early in the breeding season this species is most commonly seen inserting its long bill into the flowers of *Opuntia*. It also takes local fruits as recorded under *magnirostris*, green sphingid caterpillars and other larvae, and not infrequently is seen eating ants. Grass seed is also taken and it sometimes takes scattered grain. Gifford (*op. cit.*, pp. 239–241) records it as feeding on the soft pulp of cactus, and the introduced oranges.

*Geospiza conirostris conirostris* from Hood.—Mostly seen picking about on the ground, also taking young *Acacia* leaves and, like *scandens*, probing *Opuntia* flowers. Gifford (*op. cit.*, pp. 225–226) records it as foraging on the rocks and beach.

*Geospiza conirostris propinqua* from Tower.—Seen probing *Opuntia* flowers and eating *Croton* fruits.

*Platyspiza crassirostris*.—Feeds mainly on blossoms (particularly those of trees), buds, and young leaves. At times comes to the ground, but there it eats young leaves of herbaceous plants, and not the foods which attracted *fortis* and *fuliginosa*. Fruits included those of *Passiflora*, *Croton*, *Cordia*, and others as in the

larger forms of *Geospiza*. Large green sphingid caterpillars were taken occasionally, but the bird dealt with these in a clumsy manner, not gripping them with its feet, or trying to kill them before eating. *Platyspiza crassirostris* does great damage to the introduced fruit, *Carica papaya*.

*Camarhynchus psittacula*.—Similar in feeding habits to *C. parvulus* (see below), searching leaves for insects, excavating in branches, and taking the fruits of *Cordia*, etc. Gifford also records it feeding on heliotrope blossoms.

*Camarhynchus parvulus*.—*C. p. parvulus* from Indefatigable and *C. p. salvini* on Chatham have similar food habits. In habits, *C. parvulus* somewhat suggests a titmouse, examining twigs, bark, crannies, and on Indefatigable particularly, the leaf clusters of *Scalesia*, for insects. It examines the ground, turning over litter for seeds and insects, and also takes nectar from flowers, including the introduced tobacco, young buds and leaf centers, and green caterpillars. *Camarhynchus parvulus* also digs trenches in branches with its bill to get at larvae and beetles. It comes to grain, but usually carries it to a tree to eat it.

*Cactospiza pallida*.—Almost exclusively insectivorous. In the coastal zone, it is found particularly on *Opuntia*, where it searches the crannies, etc., and excavates trenches for insects. In the intermediate and humid zones, it inspects leaf clusters, especially dead leaves, like *Camarhynchus* and also inspects and excavates wood for boring insects. On the ground, it turns over fallen leaves and also digs in the soil under rocks particularly for beetles. It climbs up and down the trunks and branches of trees like a nuthatch. In certain respects, it also resembles a woodpecker. When the latter has excavated in a branch for an insect, it then inserts its long tongue into the crack to withdraw the insect. *Cactospiza pallida* lacks the long tongue, but achieves the same result in a different way. Having excavated, it picks up a small twig, or in the coastal belt an *Opuntia* spine, one or two inches long, and holding it lengthwise in its bill, inserts the twig into the crack, dropping it to seize the insect as it emerges. Sometimes the bird has been seen to reject one stick, if it was too short or too pliable, and it may break off another. Sometimes it carries the stick or spine about with it as it visits one tree after another, probing it into cracks as it goes.

This remarkable habit, first recorded by Gifford (*op. cit.*, pp. 253–257) and fully confirmed by W. H. Thompson and the writer,



is one of the few recorded uses of tools in the animal kingdom outside of man. The nearest parallel in birds is the use of fruits for "bower-painting" by *Ptilonorhynchus violaceus* (Gilbert, 1939). The origin of this habit of *Cactospiza* is obscure. It is unlikely that it arose through the manipulation of nest material, as the latter is essentially pliable. It is probable that the spines of *Opuntia*, owing to their suitable lengths, were first used for probing by these birds, since *Cactospiza* frequents this plant in the coastal zone.

*Cactospiza heliobates*.—Reported by Snodgrass (1902, p. 367) to feed on insects.

*Certhidea olivacea*.—Feeds much like a warbler, searching the leaves and twigs, also the ground, for insects and making short aerial excursions for flying insects. It seems to feed almost exclusively on insects, but at times takes nectar from flowers and young green leaves. The female tends to feed closer to the ground than does the male. Gifford (*op. cit.*, pp. 220–223) noted *C. o. cinerascens* feeding on the rocks below high-tide line.

*Pinaroloxias inornata*.—Probably feeds on insects in a manner similar to *Certhidea*. Gifford (*op. cit.*, p. 242) reports, "This species combines the habits of a ground-feeding finch with those of a tree-feeding warbler."

#### SUMMARY OF FOODS AND FEEDING HABITS

The Geospizinae fall into four main groups with reference to food and feeding habits. (1) Members of the genus *Geospiza* feed mainly upon seeds on the ground, but also regularly eat flowers, young leaves and buds, fruits, and caterpillars when in season, also small insects occasionally. *Geospiza scandens* and *conirostris* also feed regularly on *Opuntia* flowers, as does *fuliginosa* occasionally. (2) *Platyspiza* feeds mainly on leaves, flowers, and fruits, occasionally taking caterpillars. (3) *Camarhynchus* and *Cactospiza* eat mainly insects picked off leaves or excavated from branches. *Camarhynchus* also eats most of the foods taken by *Geospiza*. (4) *Certhidea* feeds primarily on small insects like a warbler.

There are marked variations in food as the different types become abundant. Thus, on our arrival at the beginning of the rainy season, almost all species were eating young leaves and buds, and the nectar from the tree flowers. Several weeks later, when the

young leaves and flowers were gone, almost all the Geospizinae were eating sphingid caterpillars, of which there was a great abundance. A little later most of the Geospizinae were in the bushes eating ripe fruits. Finally, just before our departure, the species of *Geospiza*, including *G. scandens*, left the trees and bushes and fed on the newly ripened grass seed. Our visit did not cover the non-breeding period.

The heavy bills of *Geospiza magnirostris*, *fortis*, and *fuliginosa* suggest fruit- or seed-eating birds, but the slight differences between the diet of these three species cannot be the cause of their marked bill differences. The long bill of *scandens* seems adapted both to *Opuntia* flowers and to ants, but during part of the year it eats the same foods as the other forms of *Geospiza*. *Geospiza scandens* has a split tongue, in this respect resembling other pollen- or nectar-feeding birds, such as the hooded oriole (*Icterus cucullatus*) (information from E. C. Kinsey). The split tongue is much less well developed in young *scandens*. It is slightly developed in adult *fuliginosa*, which also feeds to a small extent on *Opuntia* flowers. It is absent in *fortis* and *magnirostris* which were not seen eating *Opuntia* flowers. *Geospiza c. conirostris* which, like *scandens*, regularly feeds on *Opuntia* flowers, has a bill less suitable for this purpose.

The bill of *Camarhynchus*, primarily an insect-eater, seems similar to that of *Platyspiza*, which feeds chiefly upon leaves. The bill of the former is very unlike that of *Cactospiza*, which in feeding habits resembles *Camarhynchus*. The marked differences in bill between *Camarhynchus psittacula* and *C. parvulus* do not seem to be correlated with diet. The bill of *Cactospiza* is clearly adapted for excavating in wood, and the bill of *Certhidea* for catching small insects. Hence, the bill differences in the Geospizinae can, in some cases, be correlated with differences in feeding habits, but certainly not in many others.

#### DRINK

Probably the Geospizinae obtain much of their water from drops which collect on the vegetation. *Geospiza magnirostris*, *fortis*, and *fuliginosa*, but not the closely related *scandens*, visited wells and springs when present. Gifford (*op. cit.*, pp. 239-241) also noted that *scandens* did not drink water on the ground. Perhaps it obtained sufficient water from *Opuntia* pads.

After a rain, several species were observed bathing, shaking drops over themselves from the wet vegetation. Gifford (*op. cit.*, pp. 223–224) noted *Certhidea olivacea cinerascens* bathing in sea water.

### EFFECTS OF RAIN

Members of the genus *Geospiza* seem to be singularly ill-adapted to withstand rain. During heavy downpours, they seek shelter under leaves and afterward are frequently seen in an extremely bedraggled condition, occasionally scarcely able to fly. In the coastal and intermediate zones, where the species of *Geospiza* breed, rain is normally restricted to about three months of the year, in the form of heavy showers with sunny intervals. Particularly since there are no enemies, this lack of adaptation to rain does not seem to matter. In the humid forests and in the open uplands, the rainfall is heavier and more continuous. Possibly this is one factor influencing the restriction of *G. magnirostris*, *fortis*, and *fuliginosa* to the coastal and intermediate zones for breeding. The bedraggled appearance after rain was not noticed in *Cactospiza* and other forms which normally breed in the humid zone.

### NESTS

The nest sites of all of the *Geospizinae* are similar. Indeed, as already noted, one species frequently takes over the nest of another. *Geospiza magnirostris*, *fortis*, and *fuliginosa* nest from three or four feet to 20 feet above the ground; *scandens* typically higher, rarely below 15 feet, often up to 30 feet; *conirostris* on Hood usually low, below eight feet; *Platyspiza* usually from 12 to 20 feet above the ground. *Camarhynchus* was usually found about 20 feet above the ground or higher, but perhaps nests much lower at times. *Cactospiza* typically nested 30 feet up or higher, but considerably lower in the uplands where only low trees and bushes were available. *Certhidea* nested in six-foot scrub and upward, occasionally to about 30 feet.

The nests of *scandens* were found exclusively between two terminal pads of *Opuntia*. In the coastal zone, *magnirostris*, *fortis*, and *fuliginosa* also used such a situation more commonly than any other. Occasionally here, and regularly elsewhere, their nests were placed in clumps of fine, closely growing twigs of *Acacia*, *Maytenus*, and many other shrubs.

The nests are cup-shaped below with a large, domed roof and a side entrance. Those of the larger species, especially of *Geospiza conirostris*, tend to be larger than the nests of the smaller species, but there is considerable overlapping in size. In the intermediate and humid zones, a particularly abundant epiphytic lichen forms the bulk of the nest material, together with some twigs, grass, and cotton. The latter three predominate in nests on the coast.

### HABITATS

The habitats for birds on the central Galapagos Islands can be roughly classified as follows:

1. Coastal zone, arid and characterized by the tree cacti (*Opuntia* and *Cereus*), also *Acacia* and other shrubs and trees (Figs. 1 and 2).

2. Intermediate zone, at higher elevation and inland from the coast, where some coastal trees disappear and some trees of the third zone appear.

3. Humid zone, characterized particularly by two species of trees, *Scalesia* and *Psidium*, with many epiphytic ferns and orchids (Fig. 3).

4. Above the humid zone, the area of shrubs is replaced by open country containing ferns, club mosses, liverworts, mosses and grasses. On Indefatigable, ferns and liverworts predominate, together with shrubs of *Miconia robinsoniana* (Fig. 4).

On Chatham, man has undoubtedly altered conditions in the higher areas, where extensive grasslands occur, which presumably have now been much modified by the introduced cattle and horses. Around the settlement of Progreso, guava was introduced and has now spread in a continuous belt over the higher ground, forming moderately tall trees at lower altitudes, and disappearing as a scrub growth covered with moss on the highest ground. The high points on Chatham and Indefatigable range from 2,000 to 3,000 feet in altitude.

The distribution of the different species of Geospizinae as regards their habitat may be summarized as follows:

*Geospiza magnirostris*.—Breeds throughout the coastal and intermediate zones; seen rarely on the edges of the humid zone, and then only feeding, not breeding; not abundant on Indefatigable.

*Geospiza fortis*.—Common throughout the coastal and intermediate zones, excepting where the vegetation is less than about

ten feet in height or where it forms a dense forest; neither situation is common. Occasionally visits cultivated land in the humid zone in searching for food but does not breed there. On Chatham, a few individuals were found feeding in the grasslands on the top of the island; abundant on Chatham, much less so in the southern part of Indefatigable, but, judging from collections, it is evidently abundant in the northern part of this island.

*Geospiza fuliginosa*.—Most common in the coastal zone, where it is extremely abundant, also breeds commonly in the intermediate zone. In the latter zone, it is found chiefly where the trees are fairly well spaced, being more particular in this respect than *fortis*. It regularly feeds in the humid zone and in the open grassy areas above the trees, and some individuals go through preliminary courtship behavior there. However, breeding seems normally to be restricted to the coastal and intermediate zones.

*Geospiza difficilis*.—On Tower Island, frequents the coastal zone (no other zone is represented). On Abingdon Island, Gifford and others found it primarily in the humid zone, hence it does not overlap with *fuliginosa* on this island. *Geospiza d. debilirostris* of James and Indefatigable is also said to be found primarily in the humid zone, although some specimens have been collected on the coast. Swarth (MS) recorded this species, in 1932, as commonly frequenting the low bushes and forest floor in the humid zone on Indefatigable. As noted in Section I, we failed to find these birds in 1939.

*Geospiza scandens*.—Restricted to localities where *Opuntia* occurs and in this environment usually the most abundant of all the Geospizinae. On Chatham, *Opuntia* is local in distribution and this accounts for the scarcity of specimens of *scandens* in collections from this island. The bird is common, however, on parts of the south coast. Like *magnirostris* and *fortis*, *scandens* occasionally feeds on the edges of the humid zone. On Charles Island, Gifford (*op. cit.*, p. 239) reports that it regularly visits the orange groves when the fruits are ripe, but does not do so at other times.

*Platyspiza crassirostris*.—Found wherever there are tall trees, but scarce and probably not breeding in the coastal zone; most common (moderately abundant) in the intermediate zone, particularly in the taller and denser forest, also breeding in the humid zone, and extending up to the tree limit, although very scarce at the higher levels. It regularly visits the fruit trees of the planta-

tions, especially papaya. This bird is rare in the guava belt on Chatham.

*Camarhynchus psittacula*.—Observed by us only on Indefatigable, where it was not at all common, in contrast to the other species of Geospizinae, excepting *Geospiza d. debilirostris*. Most *psittacula* were seen in the humid zone, some up to the tree limit, also breeding in the intermediate zone, and occasional birds were singing but perhaps not breeding in the coastal zone.

*Camarhynchus parvulus*.—Present but not abundant in the coastal zone, where at least some bred; abundant in the intermediate and humid zones up to the tree limit. A certain number occurred in the guava belt on the high ground on Chatham.

*Camarhynchus pauper*.—According to Snodgrass and Heller (1904, p. 288), also Gifford (*op. cit.*, p. 249), this bird breeds primarily above 1,000 feet on Charles; evidently abundant.

*Cactospiza pallida*.—Predominantly a bird of the humid zone, moderately abundant up to the tree limit, common in the intermediate zone, also present, although much less numerous, in the coastal zone; probably does not breed there. In the coastal zone, it is chiefly found feeding on *Opuntia*, which is the basis of the name "*Cactospiza*." This name, however, is inappropriate, since the bird mainly frequents the humid zone, where *Opuntia* is absent. On Chatham, it is one of the few Geospizinae regularly found throughout the guava belt of the high ground. It also occurs throughout the zone of open ground above the tree limit on Indefatigable, nesting in the clumps of *Miconia robinsoniana*. Swarth (MS) reports *pallida* in mangrove swamps at Conway Bay, Indefatigable.

*Cactospiza heliobates*.—All observers report that this species is confined to the mangrove swamps around Albemarle and Narborough.

*Certhidea olivacea*.—Found particularly where there are low shrubs. It has the widest habitat range of all the Geospizinae, breeding commonly in the coastal, intermediate, and humid zones, the guava belt of Chatham, and the open bracken zone on the top of Indefatigable. Excepting where shrubs are scarce, as on some parts of the coasts, it is extremely abundant, often occurring in greater numbers than the sum total of all the other Geospizinae.

*Pinaroloxias inornata*.—Reported frequenting the forest trees on Cocos Island (Gifford, *op. cit.*, pp. 242–243).



Fig. 1.—Arid coastal zone, Indefatigable Island. Photograph taken by Richard Leacock, December, 1938.



Fig. 2.—A nest of *Geospiza magnirostris* in an *Opuntia* in the arid coastal region, Indefatigable Island.



Fig. 3.—Humid forest, Indefatigable Island.  
Photograph taken by T. W. J. Taylor.



Fig. 4.—Top of Indefatigable Island showing fern and grass-land in the foreground with low forest beyond. Photograph taken by T. W. J. Taylor.



## DISCUSSION OF HABITATS

Considerable overlapping occurs between the habitats of most of the Geospizinae. The species of the genus *Geospiza*, omitting some forms of *difficilis*, breed primarily in the coastal and intermediate zones, while *Platyspiza*, *Camarhynchus*, and *Cactospiza* breed mostly in the intermediate and humid zones, and *Certhidea* is common to all the zones. However, there is a wide area where all breed side by side. *Geospiza scandens*, unlike the other species of *Geospiza*, breeds only in *Opuntia*, but this does not differentiate it from *magnirostris*, *fortis*, and *fuliginosa*, since all of these also breed commonly in *Opuntia*. The only two known instances on these islands where habitat differences separate closely related species are: (1) *G. d. difficilis* (humid zone) and *G. fuliginosa* (coastal zone) on Abingdon; and (2) *Cactospiza pallida* (humid zone) and *C. heliobates* (coastal mangrove belt) on Albemarle and Narborough. Neither of these could be studied by us.

Gauss (1939, p. 255) has expressed a common belief when he writes, "In the light of all this evidence one may claim that if two or more nearly related species live in the field in a stable association, these species certainly possess different ecological niches." However, an exception is provided by *Geospiza magnirostris* and *fortis*. Careful field study failed to reveal any differences whatever in habitat, food, feeding habits, nest site, and breeding season between these species. Furthermore they have similar plumages. They seem to differ solely in general size and in relative size of bills. Yet, normally at least, they do not interbreed. In addition, *G. fortis* and *fuliginosa*, and also *Camarhynchus psittacula* and *parrulus* have similar ecological requirements, although there are slight differences.

Although others probably exist, *G. magnirostris* and *fortis* are exceptional examples of two closely related avian species having apparently identical habitats, food, feeding, and other ecological requirements. Dr. E. Mayr, however, informs me that two closely related species of *Ptilinopus* (fruit pigeon), representing two separate colonizations, occur on the Marquesas Islands. Although not studied in the field, all known *Ptilinopus* are so similar in ecology that the two on the Marquesas are probably similar. In California, I observed *Agelaius tricolor* breeding in the identical habitat with *A. phoeniceus*, and having extremely similar feeding habits. How-

ever, there are two differences: first, *tricolor* is colonial and *phoeniceus* territorial; second, while *tricolor* always nests in sites suitable for *phoeniceus*, the reverse does not hold, *phoeniceus* being more generalized. In many other instances, two closely related species show considerable overlapping of habitat without interbreeding, for example *Parus major* and *P. caeruleus* in Britain. See Lack (1940c) for a discussion of habitat distribution and speciation.

To summarize, habitat differences would seem to have played a part in the speciation of Geospizinae in only a few cases. It is striking that as yet no form of Geospizinae has become adapted to the vacant ecological niches afforded by the extensive open grass and fern country above the tree limit on Chatham, Indefatigable, and Albemarle islands.

#### INFLUENCE OF HABITAT ON GEOGRAPHICAL DISTRIBUTION

The smaller and more barren of the Galapagos Islands do not possess intermediate or humid forests, which may account for the absence of *Cactospiza pallida* and possibly some other species on some of them. Again, forms of *Geospiza difficilis* are found in the humid zone on Abingdon and James islands but not on Bindloe, which lies between these two islands, but has no humid zone. Fourteen specimens of *G. fortis* were collected on Hood in 1905, which would seem to indicate an attempt at colonization. Apparently, however, the species has never become established, so here also a habitat factor may be involved. However, most species show similar ecological requirements. Thus when one of the species is absent from a particular island it is more likely due to its failure to reach the island in sufficient numbers to become established than to unsuitable ecological conditions.

#### BREEDING SEASON

The main breeding season of all species of Geospizinae is in the rainy season, beginning about mid-December and ending in early April. The rains clearly have considerable influence on breeding. Thus, in the intermediate zone of Chatham, breeding was well under way in late January, 1939, but had not started in the Chatham coastal zone or on the near-by island of Hood on January 30. The intermediate zone had received sufficient rain to make the vegetation green about a month before the coastal zone. Swarth (MS)

found breeding continuing into June in 1932, a year in which the rains persisted later than usual. This late breeding is not recorded in years of more normal rainfall.

In 1939, in the intermediate zone on Chatham Island, nest-building and courtship were well under way as soon as the rains began in mid-December. Rainfall was scanty during the next five weeks and the birds, excepting *Cactospiza*, did not advance further in their breeding activities. Possibly this delay in breeding was correlated with the delay in the rains, but considerably more data are needed in order to make certain of this.

From the immature specimens in collections, it is clear that in certain years at least, some breeding takes place in August and September, and possibly in nearly all months of the year.

No species is isolated from another by differences in breeding season. The rainy season occurs in the intermediate forest before it does on the coast. Correlated with this is the earlier appearance of green leaves. Consequently breeding commences about a month earlier in the intermediate zone than along the coast. Two species, *Cactospiza pallida*, found chiefly in the humid zone, and *Geospiza scandens*, found on the coast, start to breed about a month earlier than most other species in their respective habitats, but both continue breeding for several more weeks along with the other species.

### MOLT

The adults normally molt immediately after the breeding season, that is, between April and June. The immature molts are uncertain and are discussed elsewhere.

### PREDATORS

The natural predators of the Geospizinae are extremely few. The short-eared owl (*Asio galapagoensis*) has been recorded as eating *Geospiza fuliginosa* (Gifford, *op. cit.*, p. 237) and *G. fortis* (Beebe, *op. cit.*, p. 331). However, this owl is scarce, and can have only a slight effect upon the geospizid populations. Possibly the barn owl (*Tyto punctatissima*) takes an occasional ground finch, but this species also is extremely scarce. The Galapagos hawk (*Buteo galapagoensis*) is probably harmless. The Geospizinae, therefore, have virtually no natural predatory enemies. Presumably correlated with this, they show extremely little fear of man or other introduced mammals. This tameness has been rather ex-

aggregated by some writers. It is not possible to pick the birds off the bushes, and it is extremely difficult, and usually impossible, to catch them in a hand net. Normally they allow one to approach to within six to ten feet provided sudden movements are avoided. Like other birds, the Geospizinae are somewhat wilder near their nests. They are not as tame as most of the other Galapagos land birds. The hawk, for instance, will frequently allow itself to be touched without moving away. The mockingbird (*Nesomimus*) will sometimes peck at one's boots, and three individuals of the flycatcher (*Myiarchus magnirostris*) settled on our heads and bodies in an attempt to take our hair for nest material. The Geospizinae did not exhibit such lack of fear.

The introduced black rats (*Rattus rattus rattus*), which are extremely abundant on Chatham Island, probably take a heavy toll of birds' eggs and young. The cats, which have recently been introduced on Indefatigable, may in time also become a serious menace to the birds. In one instance, without creating much disturbance, a cat was able to capture one of a group of *Platyspiza crassirostris* which were feeding on the ground on some fruit. The Geospizinae would thus seem to have lost the normal reactions of a small bird to predators, owing to the absence of the latter. However, the Geospizinae occasionally attack a Galapagos hawk in the same way, although not so effectively, as small passerine birds in other countries attack hawks and owls.

#### POPULATION DENSITY

The terrain was so inaccessible on most of the islands that we found it impossible to take a census of the breeding populations. The writer has taken censuses of breeding birds in many different types of habitats in England. On the basis of this experience, he would estimate the breeding population in the intermediate forest on Chatham as about the same as that in rich British woodland, that is about 20 adult birds per acre. The different species were represented in approximately the following percentages: *Geospiza fortis*, 14; *G. fuliginosa*, 3; *Platyspiza crassirostris*, 11; *Camarhynchus parvulus*, 8; *Cactospiza pallida*, 4; *Certhidea olivacea*, 30; *Nesomimus melanotis*, 12; *Myiarchus magnirostris*, 8; *Pyrocephalus dubius*, 6; and *Dendroica petechia aureola*, 2.

This was probably the highest density of Geospizinae encountered on the islands. In other parts of the coastal and intermediate

forest, the breeding population typically varied from 10 to 20 adults per acre, and was much lower in areas of sparse vegetation correlated with more recent lava flows. The species composition varied in different places. Thus, *Geospiza fuliginosa* and *G. scandens* were usually the most common birds in the coastal region. The humid forest on Indefatigable probably supported about 10 adults per acre. Above the tree limit in the open country, the breeding density was much lower, probably similar to that of rich English heathland, that is between one and three birds per acre. The belt of taller guava on Chatham had an extremely low density of birds and few, if any, bred there. However, more were found where the guava became lower on the grassy uplands.

On Hood, the density of small land birds was fairly high (about 10 adults per acre) around the coast, but was considerably sparser inland. On Tower, the density was much lower than encountered elsewhere, perhaps between three and seven adults per acre.

Culpepper and Wenman are so small that, even if *Geospizinae* are abundant there, it is clear that the several endemic forms peculiar to these islands are represented by at most only a few thousand individuals alive at any one time, and the populations of the endemic forms on Tower cannot be much larger. This should be borne in mind in considering their evolution. Again, Daphne is only the top of a crater and Crossman a group of islets, so that the peculiar *G. fortis*  $\times$  *fuliginosa* (?) hybrid form found there can be represented by at most only a few hundred individuals alive at any one time.

## SECTION IV. COLORATION

### BLACK MALE PLUMAGE IN *GEOSPIZA*, *PLATYSPIZA*, AND *CAMARHYNCHUS*

#### DESCRIPTION

In all the species of *Geospiza*, the fully adult male plumage is black with the exception of the under-tail coverts, which are margined with white or varying shades of buff. The juvenal and postjuvenal plumages resemble that of the female, being streaked gray-brown. It is possible that certain males attain a similarly streaked type of plumage following the postjuvenal plumage. From a study of the skins, it is clear that the black feathering first appears on the front of the head, then extends gradually down the body, the abdomen being the last to become black. Males breed at all stages between the streaked and the fully black condition.

In *Platyspiza*, the adult male is black to about halfway down the breast and back; the abdomen and lower back are colored as in the immature and female, that is, the "full" male plumage in *Platyspiza* corresponds to a transition stage of plumage in immature individuals of *Geospiza*. The same is true of *Camarhynchus*, in which the black tends to be even more restricted than in *Platyspiza*, although it often extends to the upper breast. Almost completely black plumage is found very rarely in both *Platyspiza* (one collected specimen and one seen on Indefatigable) and *Camarhynchus psittacula* (one specimen collected). On the other hand, many individuals of both genera breed in streaked plumage or in an intermediate condition, the black feathering being restricted to the head, the front part of the head, or even to a small area around the bill. As in *Geospiza*, the black first appears anteriorly and gradually develops posteriorly.

In *Cactospiza pallida*, the male is normally colored like the female and immature, showing no black. However, out of hundreds of individuals seen on Indefatigable Island, one otherwise typical male had a black head. This shows that *Cactospiza* simply carries further the tendency to loss of distinctive male plumage shown by *Camarhynchus*, to which it is closely allied.



streaked or partly black plumage, as was discussed under the preceding heading. Nevertheless, Text Table 3 does give some indication of the variation which exists.

Text Table 3 is based upon all available collections and hence is much less influenced by a single, exceptional collection. Even making considerable allowance for chance variations, it is clear that Swarth (1931, 1934) is right in his general conclusion that there is inter-island variation in the number of males breeding in black, partly black, or streaked plumage. For *Geospiza*, the evidence is inconclusive, excepting that all collections and my field observations indicate an unusually high proportion of full-plumaged males for *G. magnirostris* and *G. d. difficilis* on Tower. Especially since Tower is a small island, this conclusion is reasonably certain. In *Platyspiza* and *Camarhynchus*, there are such marked differences in the proportions of males in streaked and in partly black plumage collected on the different islands that this must reflect an actual difference in the populations concerned. To cite the most striking case, out of 87 male *Camarhynchus parvulus* collected on Charles, 61 (or 70 per cent) showed black feathering, but out of 91 males collected on Chatham only 4 (or 4 per cent) showed black feathering. Field observations on Chatham confirmed this low proportion, although it is somewhat higher than the figures based upon specimens indicate. This may be due to the fact that a majority of the partly black males breed high up in the intermediate forest, while most collecting has been done near the coast.

While inter-island variation undoubtedly exists in at least several species, Swarth appears to be wrong in his additional statement that on certain islands the proportion of males showing black is low in all species. As is discussed later, his Abingdon figures are completely misleading. On Charles, there is a low percentage of males showing black in both *Platyspiza crassirostris* and *Camarhynchus pauper*, but in *C. parvulus* it is unusually high. Chatham shows a low proportion of black males in both *P. crassirostris* and *C. parvulus*; this is confirmed by field observations. The figures in Text Table 3 for *G. scandens* on Chatham are not significant, since this form has not been collected on its breeding grounds (see Section I); however, we observed many black males there.

Swarth (1931, 1934) concluded that there was an exceptionally low proportion of "fully-plumaged" males for all species on Ab-



ingdon Island. This was based on the California Academy of Sciences collection of 1905. As shown in Text Table 4, collections made in other years do not bear this out. Doubtless this difference is partly due to the seasonal variation already considered, but it is

Table 4

Plumage of male Geospizinae from Abingdon Island

Species	C. A. S. Collection				Collections elsewhere			
	Black	Partly black	Streaked	Others	Black	Partly black	Streaked	Others
<i>Geospiza maculirostris</i>	1		14		17	10	9	
<i>Geospiza fortis</i>	1		14		11	16	6	
<i>Geospiza pulchra</i>	1		8		17	10	14	
<i>Geospiza difficilis</i>			1		11	6	2	
<i>Geospiza scandens</i>					4			8
<i>Melospiza crinitirostris</i>			5			8	5	
<i>Ammodramus helix</i>			7			9	2	

so marked that one suspects that the percentage of males breeding in streaked plumage may be different in different years on the same island.

### ADULT MOLTS

Adult Geospizinae, like most passerine birds, normally undergo a complete molt once a year, just after the breeding season, that is in May or June. This is fully substantiated both by the collections and by our field observations.

There is one possible complication. In the Rothschild Collection are numerous specimens of *Geospiza* collected on south Albatraz in December, 1900. In normal years this is the beginning of the rainy season. This collection includes both some fledglings and many males in new adult plumage. Perhaps there had been an abnormal breeding period (possibly correlated with an unusual rainy period), and the males in fresh plumage had molted just after breeding. Alternatively, they might be first-year birds molting into adult plumage for the first time.

### THE CHANGE FROM STREAKED TO BLACK PLUMAGE

The situation is complicated and evidently different individuals of the same species on the same island may molt differently.\* It

\* Observations made by Robert T. Orr at the California Academy of Sciences have shown much individual variation to occur with regard to the age at which black plumage is attained in cage-reared geospizids.

is hoped that the captive birds brought to the California Academy of Sciences will aid in clarifying the sequence of the molts from streaked to full male plumage. Until then any conclusion is necessarily speculative.

On Tower, the proportion of male *G. magnirostris* and *G. difficilis* in fully black plumage is so high that one can be certain that a large proportion of the males must molt into fully black plumage before they are a year old. The same applies to *Geospiza*, *Platyspiza*, and *Camarhynchus* on other islands where the proportion of fully plumaged males is high. On the other hand, on Chatham the proportion of partly black to streaked males in *Camarhynchus parvulus salvini* is so low that one can be certain that a large proportion of the males never acquire the black plumage. For various species on other islands conditions are doubtless intermediate, some individual males acquiring "full" plumage before they are a year old and others not.

One can be certain that some individual male *Platyspiza* and *Camarhynchus* never acquire "full" plumage. However, it is not known whether all the individual male *Geospizinae* breeding in streaked plumage remain permanently in this type of plumage, or whether some of them molt into "full" plumage in the second year. The same problem is presented by the males breeding in "partial" black plumage. At least, in many cases, this plumage appears to have been acquired by a complete, not a partial, molt. In *Platyspiza* and *Camarhynchus* the proportion of males in "partial" (black-headed) plumage is so high that one can be certain that some of them never acquire the "full" black-breasted plumage. Thus, the "partial" plumage is a final stage so far as the individual in question is concerned. It is uncertain whether this applies to all the male *Geospiza*, *Platyspiza*, and *Camarhynchus* breeding in "partial" plumage, or whether some of these later molt into "full" plumage.

In the exceptionally prolonged rainy season of 1932, Swarth (MS) collected birds in streaked plumage, with black bills, normally an indication of breeding condition, well-developed gonads, but with incompletely ossified skulls, normally a sign of juvenility. Some specimens in the American Museum of Natural History, collected in 1935, show the same condition. This suggests that, as in certain tropical Ploceidae (Steinbacher, 1936), some individuals may breed when two or three months old. If this is so, such indi-

viduals would increase the numbers breeding in streaked plumage, but they certainly do not account for all cases, since most begin to breed before any birds of the same breeding season would be old enough (personal field observation).

The discussion by Mayr (1933c) on plumage variation in *Neolalage banksiana* may be referred to; however, the situation in the Geospizinae seems to be more complex than the instances which Mayr discusses.

### HORMONAL AND GENETIC CONTROL

Recent work, notably by Witschi (1935) and his colleagues, has demonstrated that male secondary sexual plumage is controlled by various hormones (different in various species of birds), and in a few instances seems mainly under genetic control. With reference to this work, the Geospizinae would provide an extremely interesting problem. Presumably hormonal factors are involved in the change from immature to black plumage. Since in *Platyspiza* and *Camarhynchus* several stages exist in an apparently permanent form, a number of genetic factors would seem to be involved. Again the "partial" plumage, perhaps a transitional stage in *Geospiza* (and therefore under hormonal control), is certainly part of the inherited constitution of the species in *Platyspiza* and *Camarhynchus*.

Two more points may be mentioned. As shown in Section V, males in streaked or "partial" plumage have, on the average, a smaller length of wing than males in "full" plumage. Also, as has been already mentioned, males in streaked or "partial" plumage tend to breed later than do males in "full" plumage. In normal passerine birds both of these facts would indicate that the males in streaked and "partial" plumage were one-year-old birds. This cannot be considered certain for the Geospizinae, hence the relation of wing length and breeding season to black male plumage requires further investigation.

### EVOLUTIONARY SIGNIFICANCE

All data appear to confirm Swarth's (1931, 1934) contention that the black male plumage of the Geospizinae is in process of being lost, not acquired. Indeed it is inconceivable that so many genera, species, and island forms should be in process of acquiring black male plumage independently. It may also be noted that

among the Geospizinae the black male plumage is best developed in the generalized genus *Geospiza*, and is reduced or absent in the specialized genera, which latter have in other respects departed farther from the ancestral fringillid type. From the data in Text Table 3, it is clear that the disappearance of the black plumage is proceeding at a different rate in different island populations of the same species. The field study provided no reason for the assumption that the black plumage had survival value to the species, and evidently the gradual disappearance of a now functionless character is taking place.

The Galapagos forms of *Pyrocephalus*, the vermilion flycatcher, also breed not infrequently in immature plumage, especially on Chatham; so perhaps does the martin, *Progne modesta*. Indeed this is a not infrequent tendency among insular land birds. Lowe (1923) notes it in *Nesospiza* on Tristan da Cunha; Murphy and Chapin (1929, pp. 20-22) find it in the form of *Pyrrhula pyrrhula* (normally a sexually dimorphic species) in the Azores, and there are numerous cases in Polynesia; see Murphy and Mathews (1928, p. 7) for *Pomarea*, and Mayr (1931-34) for *Coracina*, *Pachycephala*, *Ptilinopus*, *Myiagra*, *Clytorhynchus*, and *Petroica*. In some of the latter, namely, *Coracina lineata*, *Pachycephala pectoralis* (*P. p. feminina* and *P. p. xanthoprocta* compared with the other races), *Clytorhynchus nigrogularis*, and *Petroica multicolor*, there is, as on the Galapagos, inter-island variation in the loss of male plumage, some races showing it and others not. Again *Pomarea iphis* and *Myiagra vanikorensis* resemble *Geospiza* in that males apparently sometimes breed in plumage intermediate between the juvenal and fully adult condition. Loss of secondary sexual plumage is not confined to the birds of oceanic islands, as, for example, the instance of *Pyrrhula* in parts of Asia (Murphy and Chapin, *loc. cit.*). The tendency, however, is certainly far more common on oceanic islands than on the mainland.

The above brings up the question of what factor makes sexual selection of less importance on small islands. The function most commonly attributed to secondary sexual plumage characters is that they emphasize postures and displays, particularly sexual and threat displays (cf. Marshall, 1936, pp. 445-446). There seems to be no reason why this should be less important on small islands. For example, the Geospizinae display vigorously. Also on the Galapagos Islands, it appears curious to see two male *Pyrocephalus*

indulging in identical threat display at each other, with the one possessing brilliant vermilion feathers which emphasize the postures, the other being quite dull-colored, but apparently none the less effective.

There is, however, another function that is sometimes attributed to male secondary sexual plumage and song in birds, particularly in closely related species in which the females are similar, namely that it enables females in search of mates to recognize readily males of their own species. Hybridization is, of course, at a selective disadvantage since it is associated with a decrease in fertility. It is quite possible that the black plumage originally served this function in the ancestral Geospizinae, in which case the disappearance of the black plumage at the present time is readily understandable since, as discussed elsewhere, specific recognition now is effected primarily by bill differences, not by plumage. A similar explanation may well hold for the other known instances among the land birds of oceanic islands, since such species have normally been separated from all other species with which the females could possibly form pairs. Hence, the survival value associated with species recognition by plumage differences disappears.

As a result of the recent advances in our knowledge of the functions of threat and courtship display, there has been perhaps a tendency to overlook this other function of secondary sexual plumage, namely in species recognition. The birds in which wild hybrids probably occur most frequently are the birds of paradise (Paradisidae) (Stresemann, 1930), the hummingbirds (Trochilidae) (Stresemann, 1930, p. 14; Berlioz, 1927), the ducks (Anatidae) (Rothschild and Kinnear, 1929; Sibley, 1938), and certain gallinaceous birds, including the Phasianidae, *Tetrao* and *Lyrurus* (Poll, 1911). It seems rather more than coincidence that a list of the birds in which secondary sexual plumage is well developed would include all of these groups. Hybridization in the wild state is probably more frequent in these birds, owing to the less definite bond between the pair, than in other birds in which both of the parents care for the young. The females of many of these species are similar, indicating that close relationships exist within the families; the striking differences between the males in part reflect the selective advantage of species recognition by the females. That is, owing to an unusually great tendency to hybridization, these birds exhibit just the opposite of the process found in the

land birds of oceanic islands. The peculiar display habits and the decreased selective value of protective coloration in the male, since he does not assist with the brood, also contribute to the great development of sexual ornamentation in these birds. These factors, however, do not account for the marked differences between the species.

Sometimes, as for instance in *Pomarea* (Murphy, 1938, pp. 534-537), instead of the males of land birds of oceanic islands losing the secondary sexual plumage, the females acquire the male type of plumage. This tendency, while not found in the Galapagos, is, however, not uncommon in continental land birds (cf. Winterbottom, 1929). Further data are needed to show whether or not this phenomenon is especially common on oceanic islands, and if it is in any way connected with the loss of male plumage in other species.

#### BLACK MALE PLUMAGE IN *Pinaroloxias*

In *Pinaroloxias inornata*, as in the species of *Geospiza*, the "full" male plumage is black, and juvenal males are colored like the females. Unlike *Geospiza*, the black feathering comes in irregularly all over the body, and does not start at the head and proceed posteriorly. It is not known if breeding occurs in immature plumage.

#### RUFIOUS UNDER-TAIL COVERTS

The males of most species of *Geospiza* in fully adult plumage are entirely black except for white under-tail coverts, but those of *G. difficilis* often show rufous or occasionally buffy tips to these white feathers. The percentage showing this, and the degree of development, varies on different islands. Only two out of 17 black males on Tower Island and one out of 12 on Abingdon show any trace, and then but little. Of *G. d. debilirostris* on James, 16 out of 27 black males, and on Indefatigable, 13 out of 21 show some rufous tipping; when present, it is better developed in the birds of Indefatigable. The rufous under-tail coverts are best developed in *G. d. septentrionalis* from Culpepper and Wenman, where most of the males show it. Males of these forms in juvenal plumage also occasionally show the rufous under-tail coverts.

In *Pinaroloxias inornata*, most males have white under-tail coverts, with buffy tips sometimes occurring. This links *Pinaroloxias*

with *G. difficilis*, since males of other forms of *Geospiza* normally show no buff. However, black males of *G. d. septentrionalis*, the form nearest to *Pinaroloxias* with reference to female plumage, which is discussed later, show far more rufous in the under-tail coverts than does *Pinaroloxias*.

#### CHESTNUT THROAT PATCH

Male *Certhidea* differ from other *Geospizinae* in possessing a chestnut patch on throat and breast. Traces of a similar patch of orange or chestnut, mixed with some black streaks, occurred in a male *Geospiza fuliginosa* in streaked plumage from Wenman Island, in a male *G. d. debilirostris* in streaked plumage from Indefatigable, and in a male *Camarhynchus parvulus* from Albemarle, while a male *C. pauper* from Charles showed a buffy patch. The chestnut throat patch also occurs in the one specimen of "*Cactospiza giffordi*" and in two "*Camarhynchus conjunctus*."

Such occurrences link *Certhidea* with the other *Geospizinae*. Stresemann (1936) supposes "*Cactospiza giffordi*" and "*Camarhynchus conjunctus*" to be hybrids of *Certhidea* and *Cactospiza* and *Certhidea* and *Camarhynchus*, respectively, but hybridization with *Certhidea* cannot possibly account for the other instances. Perhaps the genetic factor, or factors, upon which the male throat patch depends is present, at least sometimes, in other *Geospizinae*. Normally its presence would be completely obliterated by the development of black plumage.

#### FEMALE PLUMAGE (omitting *Certhidea*)

Unless otherwise stated, the descriptions in this section refer both to adult females and to immatures of both sexes, since these plumages seem indistinguishable.

The plumage in *Geospiza magnirostris*, *fortis*, and *fuliginosa* (referred to hereinafter as the MFF series) is almost the same (Swarth, 1931, pp. 144, 154, 169), namely grayish-brown above and streaked below; these three species are used as the standard for comparison. While there is considerable individual variation, significant differences between populations on different islands seem to be absent. *Geospiza fortis* of Abingdon Island seems more streaked below than is normal for members of this species on other islands, but a few Chatham specimens are fully as streaked. One *fortis* and a few *fuliginosa*, several being from Chatham, are un-

streaked below and relatively pale above. Two *fuliginosa* from Bindloe have a darker ground color than any other specimens. Some from Abingdon and Bindloe are more streaked below than usual, but others are more normal and some are nearly unstreaked. Of four *fuliginosa* from Wenman, two have varied in the direction of *G. d. septentrionalis*, being rather buffy below with more olive tips to the back feathers and with a broader brown wing bar. The wing bar in the group varies from very pale buff to brown, with considerable individual variation. Possibly a greater percentage in *maguirostris* show the brown wing bar than in *fortis* and *fuliginosa*.

*Geospiza d. difficilis*, *debilirostris*, and *septentrionalis* are generally darker above and more streaked below than the MFF group (Swarth, *supra cit.*, pp. 178-186). *Geospiza difficilis* tends to be darker above than the MFF group, but there is much overlapping. As in other characters, *difficilis* (*sensu stricto*), especially on Tower, is nearer to the MFF group than is *debilirostris*. *Geospiza d. septentrionalis* is as dark above as *debilirostris*, but with prominent olivaceous tips to the feathers, especially in the rump region. The under parts of *Geospiza d. difficilis* from Tower Island are intermediate, half being nearly as streaked as the darker *fuliginosa*, others resembling typical *scandens*, while two are darker than any *fuliginosa*. *Geospiza d. difficilis* on Abingdon is similar, but has a darker ground color. In *debilirostris*, these trends are carried further, but there is wide individual variation. Many are like the darkest, most streaked *fortis*, some definitely darker, and two are as dark as typical *G. conirostris* on Hood. *Geospiza d. septentrionalis* is dark and as streaked below as average *debilirostris*, but is often distinguishable by a buffy ground color. This species also tends to be dark-headed. In *difficilis* (*sensu stricto*), the wing bar is usually brown, more rarely buffy as in the MFF series, occasionally dull rufous, and in one specimen bright rufous. Of 32 specimens of *debilirostris*, 30 show a fairly bright rufous bar. All specimens of *septentrionalis* show some rufous on the wing, often more developed than in any *debilirostris*. Hence the degree of rufous in the female's wing bar in this group runs parallel to the rufous under-tail coverts of the male (*q.v.*).

The upper parts of *Geospiza scandens* (*sensu stricto*) tend to be slightly darker and grayer, less brown than typical in the MFF group and grayer than in the *difficilis* group, lacking the olivaceous



tips, but scarcely distinguishable from *difficilis*. The under parts are distinctly darker and more streaked than the MFF group; it is streaked especially on the throat, where the markings sometimes run together to form a solid dark area. It is nearly as streaked as *septentrionalis* but does not have the buffy tinge of the latter. The wing bar is similar to the MFF group, but possibly fewer are pale. Birds from James, Seymour, Indefatigable, Charles, and Chatham islands seem alike. Two specimens from Albemarle are especially dark below, as dark as *G. conirostris* on Hood, but others are paler. Birds from Abingdon and Bindloe are darker both above and below, those from Abingdon especially below, those from Bindloe especially above.

The darkest female plumage in the Geospizinae is exhibited by members of the species *Geospiza conirostris conirostris*. The upper parts are as dark as in *scandens* from Bindloe, but perhaps somewhat browner. The under parts are usually darker than in *scandens*. The lightest are about as dark as the darkest *scandens* from Abingdon. The wing bar is often indistinct, otherwise as in *scandens*. The plumage of *G. c. propinqua* is indistinguishable from typical *scandens* from the central and southern islands, but is distinguishable from the *scandens* on Abingdon and Bindloe, the two islands nearest to Tower. The broad, olivaceous-brown tips to the feathers of the upper parts of *G. c. darwini* distinguish it from the MFF group and *propinqua*. The under parts are as streaked as in typical *scandens* or *propinqua* and with a buffy tinge rarely seen in these forms. The wing bar in half the specimens is brown with a rufous tinge; in the rest it is brown or buff-brown. This form differs from the MFF group in the same respects as does *septentrionalis*, but less markedly than the latter. That the three forms of *conirostris* should have such different plumages suggests that they may have evolved from *scandens* stock independently.

*Platyspiza crassirostris* is more olivaceous or brownish, less gray and less streaked above, more buffy below than in the MFF group. The wing bar is as variable as in the MFF group, often brown with a touch of rufous, usually pale and often inconspicuous. Slight differences apparent in series from different islands are perhaps due merely to differences in degree of wear of the feathers, but birds from Abingdon, also Chatham, perhaps have more pronounced olivaceous tips to the feathers of the upper parts, and as a result, Abingdon birds seem almost barred above.

The forms of the *Camarhynchus psittacula* superspecies are typically paler and less streaked and nearly always more olivaceous than in the MFF group. *Camarhynchus psittacula* is gray-brown above and whitish below (Swarth, 1931, p. 216). The wing bar is normally pale buff or neutral. *Camarhynchus habeli* is usually grayer above, less olivaceous, and darker than *psittacula*; the under parts and wing bar are similar to *psittacula*. *Camarhynchus pauper* is darker with darker streaks, browner, less gray above than *psittacula*. The under parts are typically streaked, but in a few immaculate. Two females show a buffy patch on throat and breast. Wide variation occurs in the wing bar, but it is more often brown than in *psittacula*. *Camarhynchus affinis* from Albemarle is intermediate between *psittacula* and *pauper*, and probably is nearer *psittacula*, from which it differs in all the tendencies shown by *pauper*; it intergrades with both. *Camarhynchus* "incertus" or *Camarhynchus affinis* from James, Indefatigable, and other islands (for taxonomic position see Section I) resembles *affinis* from Albemarle in the plumage of the upper parts, being browner not grayer; the under parts are intermediate, but none are as immaculate as the extreme in *psittacula*.

*Camarhynchus parvulus parvulus* resembles typical *psittacula* above. Some are streaked below and others are not. Birds from Albemarle are perhaps more streaked below than those from other islands. The wing bar is like *psittacula*. The upper parts of *C. p. salvini* are extremely similar to typical *pauper*, but the brighter birds show a yellow or greenish tinge. The under parts are yellower than *parvulus* and more individuals are streaked.

"*Camarhynchus conjunctus*" is represented by two males perhaps in juvenal plumage. This is probably not a valid species. In bill and plumage, it seems intermediate between *parvulus* and *Certhidea olivacea ridgwayi*.

"*Camarhynchus aureus*," represented by one male possibly in juvenal plumage, is probably not a valid species. It seems intermediate between *parvulus* and *Certhidea olivacea luteola*.

*Cactospiza pallida*, together with some forms in the *Camarhynchus psittacula* superspecies, is the palest of the Geospizinae. Specimens of *Cactospiza p. pallida*, from James Island, are very gray above, especially on the head, resembling the grayest *Camarhynchus psittacula*; those from Indefatigable are much more olive, being more olive than *psittacula*; those from Duncan are but

slightly less olive. Birds from south Albemarle (formerly separated as *C. p. producta*) also show an olivaceous tinge, less marked than in birds from Duncan; they closely resemble typical *psittacula* except that they are not noticeably barred. Specimens from north Albemarle (formerly called *C. p. producta*) are almost as gray as birds from James. The color differences between specimens from James and Indefatigable seem more pronounced than between some races of *Certhidea*, perhaps enough to justify reviving the name *hypoleuca* (Ridgway). The specimens are normally immaculate below, but a few show slight streaking on the breast. Birds from James are palest and resemble the palest *psittacula*; birds from Indefatigable and Duncan are more buff than gray; those from south Albemarle intermediate; those from north Albemarle similar to those of James. The wing bar shows as much individual variation as in most groups, varying from sandy to pale buff. It is palest in birds from James, and brownest in the more olivaceous forms, especially on Indefatigable and Chatham. *Cactospiza p. striatipecta*, from Chatham Island, is olivaceous above and often has traces of darker barring, especially on the head, in which it resembles *Camarhynchus psittacula*. It is nearest to the Duncan birds. However, it is more olivaceous than most *psittacula*, although overlapping occurs. *Cactospiza p. striatipecta* from Chatham is streaked below. *Cactospiza heliobates* is darker above than *pallida* and as dark as the MFF group, but with olive not pale gray tips to the feathers. The under parts are more streaked than in *pallida*, in this respect resembling *Camarhynchus pauper*, but not as heavily streaked as in the MFF group. The wing bar is inconspicuous, usually brown. "*Cactospiza giffordi*," represented by one male, perhaps in juvenal plumage, is probably not a valid species. The upper parts are darker and less olivaceous than typical *pallida* or typical *Certhidea o. olivacea* from Indefatigable. The under parts show a faint green-olive tinge, slightly distinguishable from typical *pallida* or *C. o. olivacea*. Traces of orange on the breast suggest *Certhidea*; otherwise it might have been considered simply a dwarf *Cactospiza pallida*. The miniature *C. pallida* seen on Indefatigable and perhaps referable to this form (see Section I) had plumage identical with *pallida*, and showed no trace of buff or orange on the throat.

*Pinaroloxias inornata* from Cocos Island is similar to *G. d. septentrionalis*. The upper parts are somewhat darker; the feathers

show similar olivaceous tips which are brighter and more extensive, especially in the rump region. The under parts have a buffy tinge. This species has a type of ventral streaking similar to *septrionalis*, but is less streaked on the breast, and does not show the dark throat, so appears paler. It has a well-developed rufous wing bar as in *septrionalis*. In both male and female plumage, this species resembles *G. d. septrionalis*, although in bill and feeding habits it resembles *Certhidea*.

### PLUMAGE VARIATIONS IN ADULT *CERTHIDEA*

In the following discussion, the male and female plumages are not described separately because, in the various species of *Certhidea*, the plumage of the sexes is similar.

The forms from the different islands are extremely similar in the plumage of the upper parts. All have a general brown-gray coloration, with some greenish-olive. Some are browner, some grayer, some paler, some more olive. Some individuals of each island form overlap in characters with at least one, and often with several other forms, the olive tinge being especially variable.

The several forms differ in the percentage of individuals showing a rufous wing bar, but this is of little value as a diagnostic character and is difficult to classify, particularly since occasionally in the same specimen some wing coverts may be buff, some brown, and some rufous. For description of the species see Swarth (1931, pp. 250-267).

Only one form, *Certhidia o. olivacea*, shows some indication of inter-island variation. The specimens from James Island are dull brownish-gray above, with some olive; those from Albemarle are similar but are slightly more olivaceous; those from Indefatigable are appreciably more greenish-olive, slightly paler than on Albemarle, but with some overlapping. Eight specimens from Crossman seem grayer and less olivaceous than Albemarle specimens, and look somewhat like *ridgwayi*, but all are too worn for a definite decision. The under parts are pale olive-buff. Many Indefatigable birds seem somewhat more olive-buff than the others; the Crossman specimens are too worn for comparison, but seem buff not olive, and they look not unlike *becki*. In specimens from James Island, the wing bar is bright rufous; about half show a rather dull rufous brown, the rest being brown-buff or inconspicuous. More than half

the Albemarle specimens show a rufous wing bar, but it is frequently a darker rufous-brown, and in more than one-third of the specimens the bar is buff or is absent.

It would be valuable to know the immature plumages of the various forms of *Certhidea*, but the present series is too small for generalized descriptions, and possibly there are individual variations. Swarth described the few that are known. The streaked immature plumage of *C. o. ridgwayi* is of special interest, as it appears to link *Certhidea* with the other Geospizinae.

The only secondary sexual plumage character is the chestnut or orange coloring on the throat and breast of the male. This is extremely well developed in *Certhidea o. olivacea* from James Island, less so in *olivacea* from Albemarle Island, and appreciably less in *olivacea* from Indefatigable and Duncan islands. *Certhidea o. ridgwayi* from Charles shows less development of this coloring, although many specimens still possess it. In *C. o. becki*, every adult male specimen shows definite traces but less intense in color and the area of the patch is small. *Certhidea o. fusca*, *C. o. mentalis*, and *C. o. luteola* show traces only in some individuals. Indeed some writers have described the patch as being absent in these forms. Finally, in *C. o. bifasciata* and *C. o. cinerascens* there is only a slight trace in a very few individuals examined.

Ten females, five from Albemarle, and one each from Narborough, James, Jervis, Duncan, and Barrington islands, show some chestnut on the throat and breast. Such a number of specimens could not be due entirely to collectors' error in sexing the birds. Occasionally females showing male coloration are found in other species of birds. This may sometimes be correlated with abnormalities of the sex organs.

Plumage differences are the main criterion for separating the various forms of *Certhidea*. Swarth gave different names to the forms on most of the islands, but united the birds on James, Indefatigable, Duncan, and Albemarle. In the latter, he seems to have been influenced, perhaps unduly, by one character, namely the chestnut throat patch of the male. When the other plumage characters are considered, it is perhaps justifiable to separate the birds from James, Indefatigable, and Albemarle. Thus, excepting for the male's chestnut patch, *C. o. olivacea* of Indefatigable more closely resembles *luteola* of Chatham than it does *olivacea* of James. An additional point, which only further collecting can de-

termine, is the possible distinctness of the Crossman specimens, the eight males examined being in too worn plumage to be of value. There are no diagnostic characters of plumage completely separating one form of *Certhidea* from the others; in almost every form some individuals overlap with some specimens of another form. It is curious that the birds of Culpepper and Wenman islands in the extreme north should come closest to those of Charles in the extreme south, while those from Abingdon and Bindloe in the north come closest to those from Hood in the south. Conceivably this might be due to evolution among the birds of the central islands leaving those on the extremities unchanged. A possible alternative is convergent evolution. Another curious instance is the resemblance between the birds of Chatham and Indefatigable, whereas those on Barrington, which lies between these two islands, are different. In view of these difficulties, it does not seem practicable to attempt to unite the forms on the different islands in one evolutionary tree.

#### DISCUSSION OF PLUMAGE VARIATIONS IN THE GEOSPIZINAE

All the data uphold the view that the black male plumage of the Geospizinae is in the process of being lost. One can be less certain whether *Certhidea* is in the process of losing or acquiring the chestnut throat patch in the male. The apparent absence of any display correlated with this coloration makes it seem probable that it is being lost, not acquired, and this fits the general geospizid trend of loss of male secondary sexual characters. If the throat patch is being lost, one wonders how and when it was acquired, since *Certhidea* is certainly one of the Geospizinae, and hence presumably evolved from an ancestral form with black male plumage. A possible explanation is that the genetic factor or factors for this throat patch were present in the ancestral Geospizinae, but were masked by the subsequent development of black feathering, a view independently suggested by the sporadic occurrence of the throat patch in male *Geospiza* and *Camarhynchus*, already mentioned. That black coloration may conceal an underlying pattern is shown by Pycraft (1925, p. 274) who figures an isabelline variety of the rook (*Corvus frugilegus*), revealing a color pattern which was previously unsuspected, and which is normally concealed completely by the black plumage.

In female plumage, the different species of Geospizinae and the different island forms of the same species differ mainly in the shades of brown, gray, olive, etc., of the upper parts; in the degrees of streaking of the under parts, and in the coloration of the wing bars. All recent work indicates that such differences are inherited. However, the differences do not seem to be adaptive. The various Galapagos Islands provide extremely similar environments, and the various species and island forms vary in a most haphazard way both with reference to the same species on different islands, and to different species on the same island. Thus, *Cactospiza pallida* is grayer on James and north Albemarle islands, more olive on Indefatigable and south Albemarle, and more streaked on Chatham. As compared with the form on James and Indefatigable, the *Camarhynchus psittacula* superspecies is grayer on Abingdon and Bindloe, browner and somewhat streaked on Albemarle, while on Charles the form presumably derived from Albemarle is browner and more streaked, and the form derived from Indefatigable closely resembles typical *psittacula*. The best development of the rufous wing bar in the Geospizinae occurs in *Certhidea o. olivacea* on Albemarle and in *Geospiza d. septentrionalis* on Culpepper and Wenman. *Geospiza d. difficilis* on Abingdon and *G. d. debilirostris* frequent the humid zone, and differ from other forms of *Geospiza* in being darker and more streaked, the same trend being shown by *G. scandens*, which is typical of the arid coastal belt, while the other forms of Geospizinae characteristic of the humid belt, notably *Cactospiza pallida*, are much paler than *Geospiza*. Also the percentage of male *Platypiza* and *Camarhynchus* in partially black plumage is different on the various islands, with no general trends or island correlations, as already discussed.

Many more examples of such haphazard variation could be cited. No species shows any established trend of color variation except for the possible radial distribution in *Certhidea*, already mentioned. In most cases, several species do not vary in the same direction on the same island. A possible exception is that, on Culpepper, *Geospiza conirostris darwini* and two of the four specimens of *G. fuliginosa* (all possibly stragglers and conceivably hybrids with *G. d. septentrionalis*) show a tendency toward a rufous-brown wing bar, buff on the under parts and olivaceous tips to the back feathers, similar to the way in which *G. d. septentrionalis* differs from most other forms of *Geospiza*. Furthermore,

there is possibly a tendency for *G. fortis* and *G. fuliginosa* to be slightly darker and more streaked on Abingdon Island; this also applies to *G. scandens* there. Both *Camarhynchus parvulus* and *Certhidea* are greener on Chatham than elsewhere. Such instances, however, are rare, and in no instance are all of the forms of Geospizinae on the same island affected similarly. Hence, the variations seem most probably to be due to chance. All present evidence is in favor of the supposition that in the Geospizinae the plumage differences between species, and between island forms of the same species, are not adaptive; in this there is agreement with the variations shown in size of bill and wing (see full discussion later).

In the Geospizinae, plumage characters seem to have been more conservative in evolution than bill characters. Probably bill differences have been evolved more rapidly than plumage differences. In mainland birds, plumage characters are usually much more variable than are structural characters, but in general among insular birds structural variations seem to be relatively more pronounced, as is discussed later. Hence, among insular birds, plumage is sometimes a more reliable guide to relationships than are structural characters; this is well shown among the Geospizinae by *Cactospiza pallida* and *Geospiza scandens* which were formerly united on account of bill characters in the genus "*Cactornis*." Plumage characters indicate that *pallida* is much more closely related to *Camarhynchus*, and *G. scandens* to other forms of *Geospiza* than either is to the other. Habits and other characters fully support this conclusion.

### COLORATION OF THE BILL.

As reported by Swarth (1931), the bill in all Geospizinae of both sexes is normally dark in the breeding season, and pale outside of the breeding season. A similar change occurs in certain Ploceidae, and Witschi (1935) has recently experimented on the hormones controlling this. From the large available series, it is clear that the black males of the species of *Geospiza* and the partially black "full-plumaged" males of the forms of *Platyspiza* and *Camarhynchus* develop the dark bill at the beginning of the breeding season earlier than do either adult females or young males. Occasionally males, and more often females, breed with a bill which is only partially dark. This occurs particularly in female



*Certhidea*, but was also observed in *Geospiza magnirostris*, *fortis*, *fuliginosa*, and *scandens*.

The progressive changes in the coloration of the bill in the juvenile have not yet been worked out. Some young leave the nest with an entirely light-colored bill; in many it is dark above and yellowish below. Whether the latter changes to plain yellow or pinkish-yellow during the non-breeding season, like that of an adult, is not known. In this partially dark condition, the bill of the immature closely resembles that of adults who are changing from breeding to non-breeding condition. Hence, color of bill does not differentiate adult from immature specimens. On the other hand, several specimens collected near the end of the breeding season, with almost unossified skulls, and, therefore, presumably young hatched a month or two before, sometimes showed completely dark bills. It would appear as though none of the supposed characteristics of sexual maturity in the *Geospizinae*, that is black male plumage, dark bill, and ossified skull, are strictly correlated with the development of the sex organs.

## SECTION V. VARIATIONS IN BILL AND WING

Some species of *Geospizinae* are so variable that to base conclusions on ten selected specimens, as did Swarth (1931), may be misleading. Actually, the whole group has been so extensively collected that it is extremely suitable for a general statistical study, and I therefore measured almost all of the specimens available in museum collections. As can be seen from the tables which follow, the majority of the species are adequately represented from most of the islands on which they occur. The actual measurements are, of course, far too extensive for publication, but since other workers may find them valuable, I am depositing copies with the California Academy of Sciences and with the British Museum, Natural History. Modern statistical workers consider it important that when the actual measurements cannot be published, at least the frequency distributions should be. These also, however, are too bulky to publish, so I am depositing copies with the two above-mentioned institutions and also with the United States National Museum, Washington, D.C., so that those interested may consult them.

### METHODS OF MEASUREMENT

The *Geospizinae* vary mainly with reference to bill, so that for each species I measured the culmen and the depth of the bill. Originally, I used the standard culmen measurement, that is from the tip of the bill to the place where the culmen joins the skull, but I found that, particularly in *Geospiza magnirostris*, *Platyspiza crassirostris*, and *Certhidea olivacea*, I was unable to estimate accurately the exact place where the culmen ended on the skull. Thus measurements of the same specimens taken a month or two later sometimes gave different results. Dr. Alden H. Miller informed me that he experienced similar difficulty in his study of the genus *Junco*, and at his suggestion I measured the culmen from the anterior part of the nostril opening to the tip of the bill. This is an extremely reliable measurement. It is unfortunate that I could not use the whole culmen, as, until this time, it has been the standard bill measurement used by taxonomists working on this group. Furthermore, in one or two species, notably *G. magnirostris* and *G. fortis*, there is a greater difference when the whole culmen is compared than when the culmen as measured from the nostril is used.

Possibly, had I been more experienced in measuring birds, I could have taken the whole culmen measurement accurately, but after three months of intensive work I found it still unreliable. Wherever, in the present text, the word "culmen" is used it refers to the length of the culmen from the nostril, and not to the whole culmen, unless expressly stated. Swarth (1931, pp. 137-270) records a set of measurements of the whole culmen for each species.

The depth of the bill was measured at the base, with the bill closed. It is sometimes difficult to be certain of the position of the base of the bill, but I found this measurement much less liable to personal variation than was that of the measurement of the whole culmen. In some specimens, the stuffing in the mouth prevented the bill from closing properly; such specimens were not measured. In *Certhidea olivacea*, the bill is so shallow that the degree of error is considerable; hence the measurement for the depth of the bill in this species is not of great value.

In addition to these two bill measurements, I measured the length of the wing in the standard manner, that is from the carpal joint to the end of the longest primary in the flattened wing.

The culmen (from nostril) and the depth of the bill were measured with a pair of dial calipers, kindly loaned by the California Academy of Sciences, except for the specimens in the British Museum, Natural History, for which I used calipers with a vernier scale. Both of these instruments recorded to 0.1 mm. which is a finer unit than the error in estimating the limits of the bill to be measured. The wing was measured with a millimeter rule, and recorded to the nearest millimeter. In the tables which follow, the number of the specimens measured is given first (N), then the mean (M), followed by the standard deviation ( $\sigma$ ). For calculating the mean and standard deviation, the actual measurements were used, and they were not first grouped into broader divisions. In addition to these, I also include the range of each form, since, although the standard deviation gives a more accurate indication of the range of variation, the maximum and minimum specimens measured have often formed a standard part of taxonomic procedure.

Birds collected shortly after they had left the nest were excluded. The bills of such individuals were usually dark above and pink or yellow below. All specimens in streaked plumage with bills of this color collected between March (earlier for *G. scandens* and *Cacto-*

*spiza*) and June were rejected, since most young leave the nest at this season. The color of the bill of the adult is changing from black to yellowish during the latter part of this period, so that the rejected specimens undoubtedly included a number of adults. However, to be on the safe side all specimens with partly dark and partly pale bills at this season were excluded, except for males which already showed complete or partially black plumage, and which could safely be included as adults. The bill of an immature individual is probably fully grown, or very nearly so, two or three months after it has left the nest. The only immatures which may conceivably have been included among the adults measured were those that emerged from nests at an unusual time of year. This number is certainly small, and any which might have been immature, as indicated by plumage or color of bill, were rejected, irrespective of season.

#### SIZE VARIATIONS DUE TO AGE

Males of *Geospiza* spp. upon leaving the nest possess plumage essentially similar to that of the female; later the fully black plumage is assumed. It is uncertain at what age the black plumage is acquired, and whether or not this varies individually. A great many males breed in streaked or partially black plumage, but it seems reasonable to assume that, on the whole, males in streaked plumage are younger than those in fully black plumage. The same may apply to partially black males in *Platyspiza* and *Camarhynchus*.

It is well known in many birds that males several years old have a longer wing than first-year males. Hence for the wing measurement in the species of *Geospiza* and *Pinaroloxias* only fully black males were included. In *Platyspiza* and *Camarhynchus*, only males showing some black in the plumage were measured. That the older birds, as indicated by their plumage, have a longer wing is demonstrated in Text Table 5, where typical examples of each species are given.

There is also the possibility that the older males have larger bills, although this has rarely been recorded in birds. Mayr (1934a) cites this in a study of the hornbill (*Rhyticeros plicatus*). To test this, Text Tables 6 and 7 were prepared.

Tables 6 and 7 show that there is a significant difference in the mean bill size for black males as compared with males in streaked

Table 4

Variation in Wing Length with Respect to Sex and Age in the Geoplineae

Species	Island	Black Males No. Length	Partly Black Males No. Length	Partly Black & Streaked Males No. Length	Streaked Males No. Length	Families No. Length
<i>Geoplinea magnirostris</i>	Ahiketon	18 52.2 1.87	10 81.6 2.88		23 80.0 2.01	29 78.7 2.04
" "	James	16 81.9 2.12	12 84.5 1.47		18 81.2 1.89	21 80.0 1.04
" <i>fortis</i>	Chatham	56 75.7 2.08	25 71.5 2.22		28 69.0 2.60	64 69.6 2.59
" "	Charles	102 72.1 2.47	48 72.5 1.00		26 70.4 2.43	97 68.8 2.30
" <i>fuliginosa</i>	Chatham	62 64.0 1.94	14 64.4 1.45		18 61.6 1.87	108 61.0 1.63
" "	Charles	41 64.0 1.64	18 65.4 1.89		27 62.1 1.36	87 62.2 1.78
<i>Pterodroma incerta</i>	Laysan	78 68.1 1.25	17 67.1 0.84		21 66.6 1.25	41 65.4 1.17
<i>Geoplinea septentrionalis</i>	Warden	26 71.4 1.54		41 71.5 1.81		15 68.5 1.12
" <i>debilis</i>	James	32 71.1 1.1		11 69.9 1.22		29 69.4 1.24
" <i>acutirostris</i>	Indefatigable	40 72.1 1.11		44 71.1 1.97		32 69.7 1.18
" "	Charles	59 71.2 1.54		45 70.4 2.07		51 68.7 1.61
" <i>longirostris</i>	Gardner (Island)	58 70.9 2.45		52 71.4 2.44		47 70.2 2.30
<i>Pterodroma externa</i>	Albemarle		54 84.1 1.87		21 82.1 1.98	26 80.8 1.04
<i>Amerythrus bairdi</i>	Hindoo		15 71.1 1.55		12 70.2 1.7	14 68.1 1.44
" <i>pauciflorus</i>	Charles		11 70.4 1.54		59 69.1 1.78	67 68.5 1.44
" <i>peruvius</i>	James		10 68.4 1.54		10 67.8 1.40	14 67.1 1.36
" "	Charles		60 64.1 1.57		16 67.9 1.54	10 65.1 1.72
" <i>p. exilis</i>	Chatham		67.4		87 64.1 1.51	4.4

Table 5

Variation in Length of Femur with Respect to Age in Male Geoplineae

Species	Island	Black Males No. Length	Partly Black Males No. Length	Partly Black & Streaked Males No. Length	Streaked Males No. Length
<i>Geoplinea magnirostris</i>	Ahiketon	18 46.0 1.54	11 47.1 1.71		22 46.0 1.43
" "	James	16 47.7 1.74	11 47.9 1.67		7 47.1 1.40
" <i>fortis</i>	Indefatigable	59 47.3 1.91	47 47.4 1.4		17 47.9 1.64
" "	Charles	56 47.5 1.56	25 47.1 1.67		21 46.1 1.77
" "	Charles	100 47.1 1.71	11 47.1 1.64		4 47.5 1.40
" <i>fuliginosa</i>	Indefatigable	51 46.4 1.71	7 47.4 1.74		14 47.1 1.40
" "	Chatham	17 47.1 1.4	5 47.1 1.67		10 46.4 1.40
" "	Charles	41 47.1 1.64	18 47.1 1.40		1 47.1 1.40
<i>Pterodroma incerta</i>	Laysan	78 47.1 1.57	17 47.1 1.57		1 47.1 1.40
<i>Geoplinea septentrionalis</i>	Warden	26 47.1 1.44		4 47.1 1.44	
" <i>debilis</i>	James	3 47.1 1.44		1 47.1 1.44	
" <i>acutirostris</i>	Indefatigable	4 47.1 1.44		47 47.1 1.44	
" "	Charles	15 47.1 1.44		44 47.1 1.44	
" <i>longirostris</i>	Gardner (Island)	58 47.1 1.44		4 47.1 1.44	
<i>Pterodroma externa</i>	Albemarle		54 47.1 1.44		21 47.1 1.44
" "	Indefatigable		17 47.1 1.44		1 47.1 1.44
" "	Chatham		7 47.1 1.44		21 47.1 1.44
<i>Amerythrus bairdi</i>	Hindoo		15 47.1 1.44		1 47.1 1.44
" <i>pauciflorus</i>	Charles		11 47.1 1.44		5 47.1 1.44
" <i>peruvius</i>	James		10 47.1 1.44		10 47.1 1.44
" "	Charles		60 47.1 1.44		16 47.1 1.44

Table 6

Variation in Depth of Bill with Respect to Age in Male Geoplineae

Species	Island	Black Males No. Depth	Partly Black Males No. Depth	Partly Black & Streaked Males No. Depth	Streaked Males No. Depth
<i>Geoplinea magnirostris</i>	Ahiketon	16 9.99 66.7			23 10.19 1.045
" <i>fortis</i>	Charles	100 10.35 9.7			26 10.14 1.044
" <i>fuliginosa</i>	Chatham	57 8.7 40.6			26 7.88 41.2
" "	Charles	31 8.4 38.8			24 7.8 2.96
" <i>septentrionalis</i>	Warden	26 8.46 26.7		18 8.23 1.15	
" <i>acutirostris</i>	Charles	49 9.44 59.4		41 9.41 1.96	
<i>Pterodroma externa</i>	Albemarle		17 10.18 44.0		14 11.6 1.548
<i>Amerythrus bairdi</i>	Hindoo		11 10.60 30.0		9 10.45 30.0
" <i>pauciflorus</i>	Charles		18 8.96 36.5		47 8.79 44.0
" <i>peruvius</i>	Charles		14 7.48 27.5		20 7.51 30.5

plumage in *Geospiza fuliginosa* on Chatham (in culmen only), for *Platyspiza crassirostris* on several islands, and for *Camarhynchus psittacula* on James and Indefatigable (depth of bill only). In each instance, the older males are the larger. For other species and island forms, the differences are either nonexistent or, when present, are extremely small, and, treated separately, are usually not statistically significant. However, when the series is considered as a whole, there is possibly a tendency for the older males to be slightly larger. In view of this slight difference, some workers might prefer to use only the measurements of older males when comparing different forms. On the other hand, if all the available males are used (excluding fledglings) many more specimens are available, so that this larger grouping is in some respects preferable, particularly since the difference in mean is so small (rarely more than 0.1 mm.). The position is complicated further since, particularly in a number of forms, some males never attain the black plumage. This percentage varies on the different islands, so that it is difficult to know whether all males, or only those showing black, are more "typical" of the species (which is, after all, primarily a breeding unit). Accordingly, in the Main Tables I-X, pp. 142-151, all males are grouped together for bill measurements, but, following the Main Tables, the measurements for older males alone are given.

In *Geospiza magnirostris* and *G. fortis*, there is one more difference noticeable when the bills of males in black and streaked plumages are compared, namely that the black males seem to be less variable than the streaked males or than all of the males taken together. No such difference is apparent in the other species, and in *G. magnirostris* it seems to apply only to depth of bill. (See Text Table 8, p. 86, and compare the figures in the Main Tables for other species.)

In the species of *Cactospiza*, the immature males cannot be distinguished from the older ones, since the plumages are similar. This also applies to females of all species, so that these represent birds of all ages.

#### SEX DIFFERENCES

In every species except one, the females have smaller bills than the males, both with reference to culmen and to depth of bill. This slight difference possibly has a similar genetic basis to that of such

sex differences as stature in man, discussed by Danforth (1939, pp. 344-345). Contrary to the other species, in *Certhidea olivacea* the female has a longer bill than the male. In this species, the female has different feeding habits from the male, foraging nearer the ground. Whether or not, however, the bill difference is correlated with feeding habits is unknown. (For details see the Main Tables, pp. 142-151). In variability of size of bill, male and female show little difference in any species.

In wing size, Text Table 5 indicates that in the forms of *Geospiza* the black males have a longer wing than the partly black males, which in turn average longer than the streaked males, and these average longer than the females. The same applies to the partly black males as compared with streaked males and with the females in members of the genera *Platyspiza* and *Camarhynchus*. In all the species, including those of the genus *Certhidea*, the wings of the males average longer than those of the females.

From the Main Tables, it would appear that in wing length the female is more variable than the male. This presumably results from the fact that wing length varies with age. Thus while the young males can, in most species, be separated by plumage, the females cannot, and must be grouped together. When the males are grouped together, as was necessary in *Cactospiza*, the standard deviation of the male wing is as large as in the female.

#### SPECIMENS OF QUESTIONABLE IDENTITY

As already noted in Section I, a number of specimens do not conform to any of the known species. A few seem to be aberrant specimens, while others are intermediate in characters between two described species. These specimens have not been included in the Main Tables, but are listed separately in Text Table 16. I have also included in this same list of questionable specimens a number which I have assigned to described species, since their allocation is partly a matter of personal opinion, and other authorities might differ from me. Obviously, the inclusion of abnormal specimens in the calculation of the mean and standard deviation in an island form will affect both of these figures, particularly the standard deviation, and especially if not many specimens are available.

For *Geospiza magnirostris* and *G. fortis*, I have included in the tables not only the most questionable specimens but also a number of other specimens, in order to illustrate the similarity in measure-

ments of these two species. It is unfortunate that the most reliable character separating these two species is the length of the whole culmen, which, as stated elsewhere, I could not measure accurately. The shape of the culmen often gives a different appearance to the birds and makes identification of large specimens of *G. fortis* and small specimens of *G. magnirostris* easier than would appear from the table of measurements.

### DIFFERENCES BETWEEN ISLAND POPULATIONS OF THE SAME SPECIES

#### 1. *Differences in mean*

In the Main Tables I-X the population of each island has been treated separately, and, in addition, the populations from north and south Albemarle have been kept distinct as these two localities are far apart. Nearly all specimens labeled "north Albemarle" were collected at Tagus Cove, those labeled "south Albemarle" at Iguana Cove in the southwest and Vilamil in the southeast. For *Geospiza fuliginosa* some specimens are also available from central Albemarle, mostly labeled Elizabeth Bay or Perry Isthmus.

It can be seen that in many species the island forms are slightly different. In a few instances the differences are sufficiently large for the forms to have received separate subspecific names. In many other cases, the degree of difference is too small to justify a nomenclatural separation, although the differences are statistically significant. On the whole, as compared with other oceanic islands, the differences between island forms on the Galapagos are rather slight.

From the summaries which follow, it will be seen that no species shows any completely regular trend of variation, that is from north to south, or in any other direction, or radially from any one island outward. In *G. fortis*, there is a tendency for increasing size in one direction, but it is not completely regular, and in *G. scandens*, the population of each island seems to be almost independent of the others. The relative independence of each island population is well shown on Bindloe, which lies between Abingdon and James. In three species, namely *G. magnirostris*, *G. fuliginosa*, and *G. scandens*, the populations on Abingdon and James are more like each other than like those on Bindloe. In the main, each island population seems to be evolving independently, but there is apparently



a little inter-island wandering, which means that the populations of neighboring islands will show some resemblances. The data for the variations in the mean bill and wing sizes for each species are as follows:

*Geospiza magnirostris*.—The largest birds are from Tower Island in the northeast. Those on Wenman, in the far northwest, average smaller. Those on Abingdon are intermediate. Bindloe is only 13 miles from Abingdon, but in bill size *magnirostris* there averages nearly a millimeter smaller, although those from James, farther south, are closely similar to those from Abingdon in size. Jervis is a small island only five miles from James, but the birds there have a significantly smaller bill. Swarth's contention that *G. magnirostris* tends to be larger in the north and smaller in the south is not altogether true, since the Wenman population in the extreme north is smaller than that on Tower, Abingdon, or James islands, and the Bindloe birds are smaller than those of James to the south. The apparent small size of birds from Indefatigable and south Albemarle (Main Table I) may not be altogether reliable, since not enough specimens were available. It is also possible that they interbreed occasionally with *G. fortis*, and that some of these hybrid specimens, not necessarily first generation, have been included under *G. magnirostris*.

Near the end of Main Table I are included the measurements of the specimens collected by Darwin, and it can be seen how much larger his "*G. magnirostris*" are than any specimens collected seventy years later. On the other hand, his "*G. strenua*" are like modern forms.

*Geospiza fortis*.—For this species Swarth claimed a trend of increasing size from north to south, but this is not altogether true. The largest birds are found on south Albemarle and Chatham, but on Charles, farther south, they average smaller, and this variable population includes some very small specimens. In bill size, birds from Abingdon and Duncan are smaller than those from other islands. Those from north Albemarle average about 1 mm. smaller in bill than those from south Albemarle. The forms on Daphne and Crossman are discussed later; they are thought to be of hybrid origin with *G. fuliginosa*. The form on Duncan is smaller than on either of the neighboring islands of Indefatigable and Albemarle, and it is conceivable that here also there has been some interbreeding with *G. fuliginosa*. In wing size, the birds on Abingdon and

Bindloe are distinctly smaller than those from other islands. Those on south Albemarle and Chatham are larger than elsewhere.

*Geospiza fuliginosa*.—The bill variations in this species are not great. The form on Bindloe Island is of interest, since it is smaller than that on Abingdon to the north and James to the south. The wing variations are also slight, but, as in *G. fortis*, the birds on Abingdon and Bindloe are significantly smaller than elsewhere. Indeed, at one time they were separated as a subspecies, *G. f. minor*, but the overlapping is too great to justify this.

*Geospiza difficilis*.—The three subspecies of this species show fairly marked differences in bill and wing size. Furthermore, each subspecies occurs on two islands, and in each such pair the populations on the two islands show significant differences in mean size, although not sufficient to justify subspecific separation. (See the Main Tables for details.)

*Geospiza scandens*.—There is a large form on Abingdon. On Bindloe, the next island to the south, there is an even larger form. On James, the next most southerly island, the form is extremely small, and all specimens can be readily separated from those on Bindloe. On Jervis, only five miles from James, the mean is significantly larger than on James, and becomes larger still on Indefatigable, south Albemarle, and Barrington to the south. It is a little smaller again on Charles in the extreme south, while the form on Chatham to the southeast has a distinctly shorter bill, although it is no less deep, than those of the central islands. In other words, regular trends are almost absent in this species, and, although specimens from James and Bindloe are readily separable from each other and therefore could be named, the specimens from the other islands overlap with both and make consistent treatment impossible. (See Section I and Frontispiece map.) Mayr (1940, pp. 262–263) records similar irregular size trends in the honey-eater (*Foulehaio carunculata*) on various Polynesian islands, which again make subspecific treatment impossible.

*Geospiza conirostris*.—It is remarkable that the population on Gardner, less than a mile from Hood, should average nearly 1 mm. smaller in wing length and both bill measurements than the population on Hood. The other forms are considered later.

*Platyspiza crassirostris*.—This species shows less variation between different islands than any other. Possibly the birds on Narborough and north Albemarle, few of which have been collected,

are slightly smaller than those elsewhere; apart from these there does not appear to be any significant variation in size of bill or wing. This stability is conceivably due to the fact that this species may wander more frequently from one island to another than do the other species. Thus, although it seems unlikely, the island populations may not be isolated from each other. *Platyspiza crassirostris* is also well separated from all the other species, and only one aberrant specimen, a dwarf bird from Narborough, has been examined.

*Camarhynchus psittacula*.—The form *habeli* on Abingdon and Bindloe islands differs not only in bill measurement, but also in shape of bill, from *psittacula* (sensu stricto) on James, Indefatigable, and other islands (Swarth, 1931, pp. 219–222). *Camarhynchus affinis* on Albemarle is smaller than *psittacula*. The unusual specimens found on the central islands, perhaps referable to *affinis*, have been discussed in Section I, as has the Duncan population. *Camarhynchus pauper* on Charles Island is discussed later.

*Camarhynchus parvulus*.—Birds from James and north Albemarle have slightly smaller bills than those on Indefatigable, south Albemarle, and Charles islands, but the differences are not sufficiently great to justify subspecific separation. On Chatham there is a larger form, *C. p. salvini*.

*Cactospiza pallida*.—The birds on James are significantly larger than those on islands to the south. Those from north Albemarle are larger than those from south Albemarle. Those from Chatham are particularly small, and have been separately named.

*Certhidea olivacea*.—The inter-island variations in this species mainly concern plumage, but there are also slight variations in measurements. In particular, the forms on the central islands, James, Indefatigable, Duncan, and Albemarle, have smaller bills than those on the islands both to the north and to the south. The birds from Charles have appreciably deeper bills than those from other islands, a difference which is more apparent to the eye than the measurements indicate. There are also slight, but significant, wing variations, and here also the birds on the central islands tend to be smaller (see Main Tables).

## 2. Differences in variability

The standard deviation gives a convenient measure of the degree of variability when comparing the island forms of the same species.

It can be seen from the Main Tables that in some species the island forms differ not only in mean, as already discussed, but also in variability in both bill and wing. The data presented in the Main Tables provide material for examining the view, first advanced by Darwin, namely that small populations are less variable than large populations. This view was recently tested statistically by Fisher (1937) for birds' eggs, and was also developed at length on theoretical grounds by Sewall Wright (1931, 1940). Environmental conditions in the coastal zone on the various Galapagos Islands would seem, so far as they affect the species of *Geospiza* and *Certhidea*, to be similar on the different islands. Hence, it is reasonable to assume that, for these species, the population on a small island will tend to be smaller than that on a large island. In the present investigation, the population must also be isolated from that of other islands because if there is regular mixing with a neighboring island, the populations of the two islands cannot be considered separately.

Culpepper and Wenman are extremely small islands, separated from the main group, and a moderate distance from each other. Tower is small and isolated, although not to the same extent. Abingdon, Bindloe, and Hood are moderately small and somewhat separated from the other islands. It should be noted that the prevailing wind is from the southeast, which means that the two easterly islands of Tower and Hood are more isolated, for birds, than their positions on the map seem to indicate. The distances between the islands are given in Text Table 1. One can, therefore, compare the populations of these smaller, more isolated islands with the populations of the larger islands, together with those of the small islands situated near them. The populations of these larger islands probably mix to some extent with those of the neighboring ones. For this investigation, all the measurements given in the Main Tables can be used except those of the wings of females. The latter must be omitted, since, as mentioned earlier, it is not a homogeneous sample, but includes birds of all ages. Hence, its variability depends upon the relative numbers of streaked and adult specimens included, which is unknown. Details are given in Text Table 8 for *Geospiza magnirostris* and *G. fortis*. I have given the values both for all males together and for those in full black plumage (see earlier discussion).

In *Geospiza magnirostris*, the birds on Wenman and Tower, the

two smallest and most isolated islands, have smaller standard deviations for all five measurements than have the birds on the larger islands. This is true for the male bill measurements whether all males or only those in fully black plumage are considered. Also, the populations on the moderately small and more or less isolated islands of Abingdon and Bindloe tend to have smaller standard deviations than those of the larger islands of James, Indefatigable, and Albemarle. As might be expected, the population on the small island of Jervis, which is close to James, has a similar variability to that of the large islands.

Table 1

Variation in Standard Deviation of Culmen, Depth of Bill and Wing Length in Various Breeding Populations  
of *Geospiza magnirostris* and *Geospiza fortis*

Island	Description	<i>Geospiza magnirostris</i>			<i>Geospiza fortis</i>		
		All Males	Black Males	Females	All Males	Black Males	Females
Wenman	Extremely small, isolated	.656	.150	.112	.899	.407	.342
Tower	Small and isolated	.599	.154	.197	1.121	.175	.142
Abingdon	Moderately small, isolated	.657	.154	.133	.941	.668	.793
Bindloe	" " "	.710	.09	.174	.914	.011	.173
James	Large, not isolated	.702	.194	1.013	1.112	.711	1.505
Indefatigable	" " "	.799	.305*	.171	1.111	.134	1.033
Jervis	Small, not isolated	.120	.177	1.59	1.067	1.145	.177
<i>Geospiza fortis</i>							
Abingdon	Moderately small, isolated	.511	.447	.153	.661	.611	.541
Bindloe	" " "	.466	.175	.115	.411	.356	.413
James	Large, not isolated	.556	.534	.599	.714	.645	.781
Indefatigable	" " "	.809	.782	.630	1.321	1.477	1.183
Harborcraft	" " "	.491	.451	.643*	.516	.516	.185
N. Albemarle	" " "	.726	.583	.880	1.055	.989	1.209
S. Albemarle	" " "	.651	.627	.917	1.169	1.112	1.474
Seymour	Small, not isolated	.780	.429	.612	.917	.553	.914
Duncan	" " "	.728	.575	.554	.962	.615	.946
Chatham	Large, moderately isolated	.662	.536	.765	1.131	.908	1.296
Charles	" " "	.983	.836	.818	1.222	.917	.963

\* Insufficient number of specimens.

*Geospiza fortis* is unfortunately not resident on Wenman, Tower, or Hood. The Hood birds were considered to be stragglers, hence they were not included. The populations on Abingdon and Bindloe tend to have smaller standard deviations in the bill measurements of both sexes than do those from the larger islands. This is not true with reference to the wing measurement of black males. Barrington

is a small island, moderately isolated, and here also the population has a small standard deviation. However, not many specimens were available. To judge from the numbers collected, *G. fortis* is considerably less numerous on James than on the islands to the south, so the James population should perhaps be considered as a moderately small one.

Hence, Text Table 8 definitely supports the views advanced by the authors mentioned above. The standard error of the standard deviation is large, so that any one case taken singly is seldom significant. All of the small island forms, however, show the same trend in all measurements excepting the black male wing in *G. fortis*, and, taken together, the data seem significant. The difference is perhaps not as great as might have been expected, considering how extremely small some of the island populations must be as compared with others. However, it must be remembered that probably no population is completely isolated, and an occasional bird wandering from one of the larger to one of the smaller islands and interbreeding there would at once make the small population more variable. The records of individuals which are known to have traveled from one island to another are given later in Text Table 14, and show that this occurrence is not uncommon.

*Geospiza fuliginosa* and *Certhidea olivacea* are both widespread species which might have been expected to show the same phenomenon of a lower variability on the small isolated islands. However, as can be seen from the Main Tables, no such tendency is apparent. It may be noted that, in general, these are less variable species than *G. magnirostris* and *G. fortis*. Here selection pressure is presumably higher, restricting random variation. *Geospiza scandens* and *Platyspiza crassirostris* also show no such tendency, but only a few specimens of *G. scandens* are available from the critical islands of Abingdon and Bindloe. *Platyspiza crassirostris* is a stable form everywhere. *Camarhynchus psittacula* cannot be considered in this connection because, judging from the numbers in collections, this species must be much more numerous on Abingdon and Bindloe than it is on James or Indefatigable. Thus, the populations on the two former islands are not necessarily smaller than those on the latter. The forms of *G. difficilis* are also difficult to compare, as they are rather distinct from each other, and it is uncertain whether *septentrionalis* of Culpepper and Wenman islands should be included in this species. Furthermore, owing to the restricted habitat

distributions of *debilirostris* on James and Indefatigable, and of *difficilis* on Abingdon, it is difficult to determine how their total numbers compare with each other. The other species of *Geospizinae* do not occur on the small isolated islands.

### CORRELATIONS BETWEEN BILL AND WING MEASUREMENTS

Text Table 9 gives correlation coefficients for culmen and wing, and for culmen and depth of bill, in typical examples of all of the principal species of *Geospizinae*. As might be expected, there is, in many species, a high correlation between the length of the culmen and the depth of the bill. This is particularly noticeable in the larger-billed species of *Geospiza*. Indeed, there is a positive correlation for culmen and depth of bill in all species investigated excepting *Cactospiza pallida* in which, strangely, there seems to be none. *Certhidea olivacea* and *Pinaroloxias inornata* were not investigated in this connection, as they have slender bills, consequently error in measurement of depth of bill is relatively great.

Table 9

Some Correlation coefficients in *Geospizinae*

Species	Island	Culmen No.	Wing Coefficient of Correlation	Culmen No.	Depth of bill Coefficient of Correlation
<i>Geospiza magnirostris</i>	All	109	+0.418		
" "	Abingdon			46	+0.833
" <i>fortis</i>	Charles	100	+0.672	171	+0.796
" "	Chatham	56	+0.401	162	+0.683
" "	Abingdon			42	+0.721
" <i>fuliginosa</i>	Anthony	61	+0.248	111	+0.869
" "	Charles	41	+0.249	71	+0.574
" <i>d. debilirostris</i>	James	32	+0.114	39	+0.515
" <i>scandens</i>	Charles	58	+0.210	88	+0.431
" <i>conirostris</i>	Hood	64	+0.491	80	+0.749
<i>Platyspiza crassirostris</i>	S. Albemarle	54	+0.477	42	+0.355
<i>Camarrhynchus pauper</i>	Charles	71	+0.61	66	+0.476
" <i>parvulus</i>	Charles	40	+0.130	54	+0.502
<i>Cactospiza pallida</i>	S. Albemarle	53	+0.049	48	+0.093
<i>Certhidea olivacea</i>	Indefatigable	32	+0.302		
<i>Pinaroloxias inornata</i>	Charles	78	-0.061		

Note. For the culmen wing correlation, only fully black males were used in the species of *Geospiza* and *Pinaroloxias*, and only males showing some black in *Platyspiza* and *Camarrhynchus*. For the culmen depth correlation, all males were used.

Correlation between length of culmen and length of wing is fairly high in a number of species, noticeably in the larger forms, but is much less marked in the smaller species. In addition, there is no correlation in *Cactospiza pallida*, or in *Pinaroloxias inornata*. The high correlation between bill and wing size in *Geospiza magnirostris*, *G. fortis*, and *G. conirostris*, which are all extremely variable species, suggests that this variability may be due partly to general size factors. A. H. Miller (1941) did not get nearly such high positive correlation of these measurements in most species of *Junco* which he investigated. This is also true of my investigation of introduced *Passer domesticus* in the United States (Lack, 1940d).

#### DIFFERENCES IN MEAN OF BILL AND WING BETWEEN SPECIES

Obviously, most species differ from each other in the mean size of bill and wing measurements, and these differences, apparent in the Main Tables, do not need discussion. However, *Geospiza magnirostris*, *fortis*, and *fuliginosa* are of special interest, since these three species have identical plumages and seem to differ from each other solely in general body size and in relative size of length and depth of bill. It is apparent from the Main Tables and the histograms shown in Figs. 5-26 that the gap between *fuliginosa* and *fortis* on the one hand, and *fortis* and *magnirostris* on the other, is much more marked on some islands, as for example on Abingdon and Bindloe, than it is on other islands, such as Indefatigable. In fact, on the latter island it is sometimes difficult to tell whether a particular specimen belongs to *magnirostris* or *fortis*, and it is also conceivable that there is a certain amount of hybridization. Furthermore, on some islands, *fortis* is extremely variable, while the gap between the species is narrow. Hence, on Indefatigable and some other islands, the smallest *fortis* are actually much closer in measurement to the largest *fuliginosa* than they are to the largest individuals of their own species. Similarly, the largest *fortis* are much closer in measurement to the smallest *magnirostris* than they are to the smallest birds of their own species. Since these species differ solely in these mensural characters, the species problem in this group is extremely interesting.

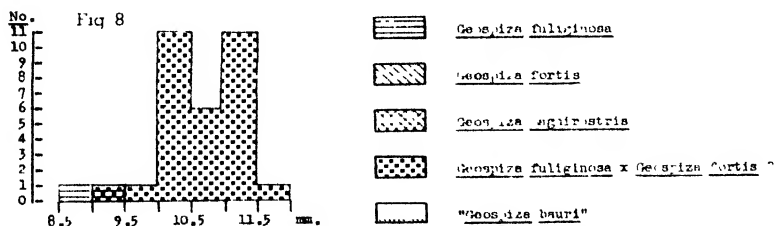
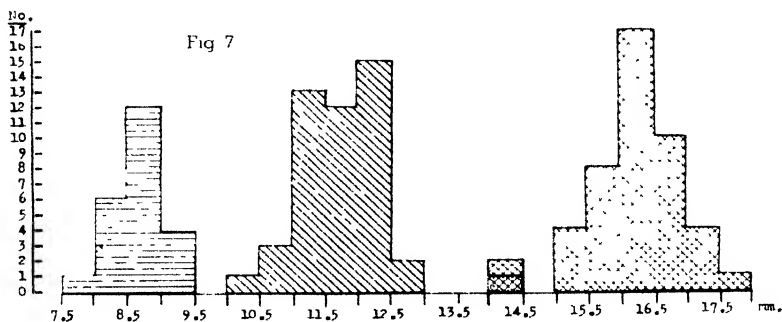
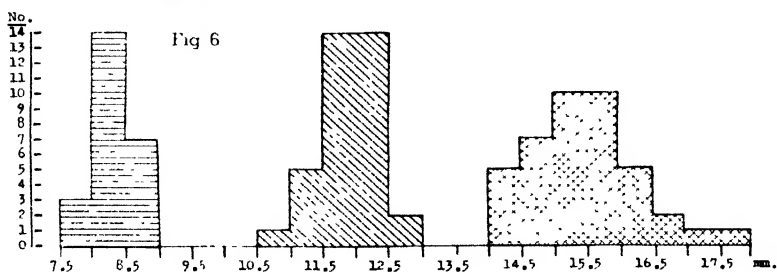
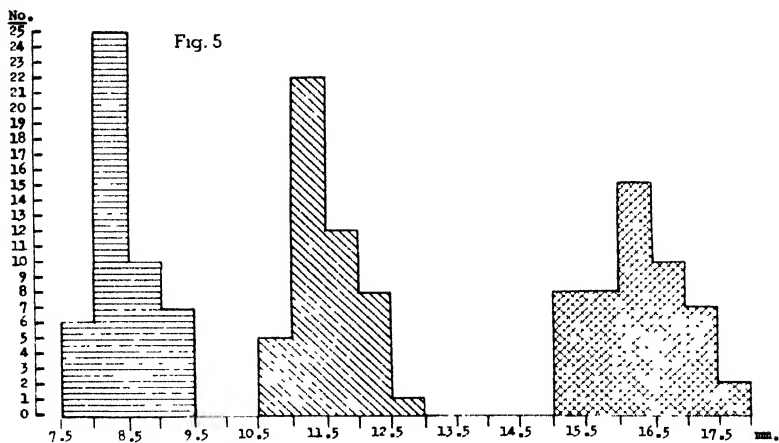
It is hardly necessary to point out that *fuliginosa*, *fortis*, and *magnirostris* are three distinct species which normally do not interbreed with each other, although they may do so occasionally. Dur-



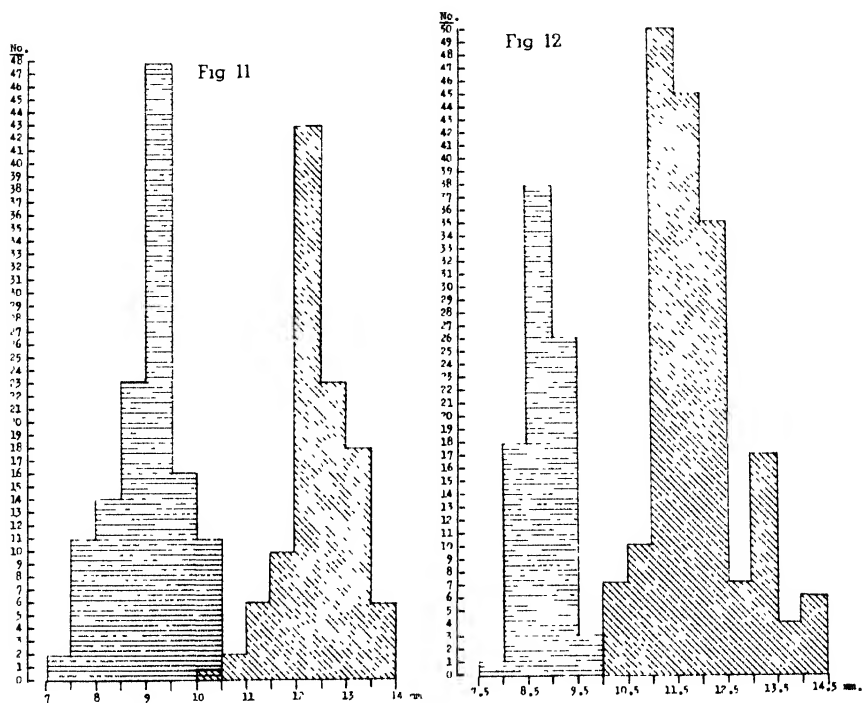
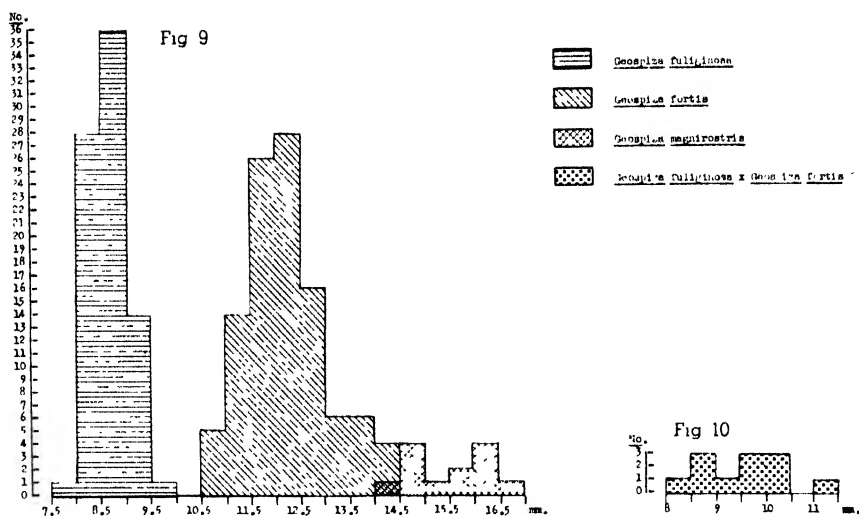
ing our stay on Chatham and Indefatigable islands, we found no evidence for interbreeding, excepting that on Indefatigable we were sometimes in doubt when one or both birds of a pair were of such size that they might be either large *fortis* or small *magnirostris*. This is perhaps worth emphasizing since it has been suggested that *magnirostris* and *fuliginosa* are two homozygous stocks which regularly interbreed with each other, producing *fortis* as a heterozygous first generation. This is definitely not true.

*Geospiza magnirostris* and *G. fortis* show a slight overlapping in measurements of culmen from nostril, depth of bill, and length of wing. Conceivably there is no overlapping in the length of the whole culmen, but here also they approach each other extremely closely. A definite statement on the degree of overlapping is impossible since with some difficult specimens one cannot be absolutely certain of identification as to species. Inspection of the Main Tables I, II, Text Table 16 of questionable specimens, and the histograms for the limits of size for different island forms of *magnirostris* and *fortis* will show the complexity of the situation. Particularly difficult are the four specimens formerly called *G. bauri* obtained on James and two similar ones from Bindloe. Had these specimens occurred on Indefatigable, they would almost certainly be ascribed to *fortis*. On Bindloe and James, however, *fortis* is small and these specimens approach more nearly *magnirostris*, especially on Bindloe, where *magnirostris* is small. Hence their position is impossible to assign with certainty (see Section I, p. 10).

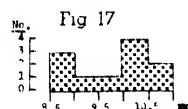
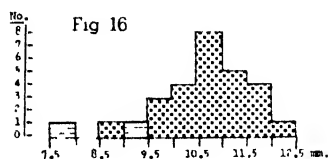
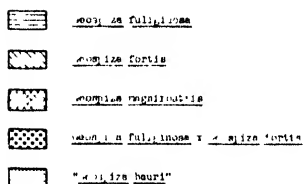
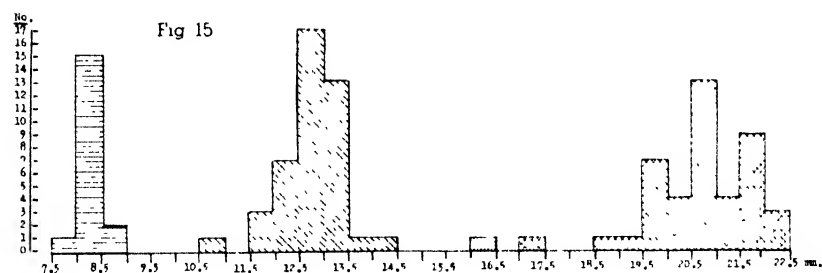
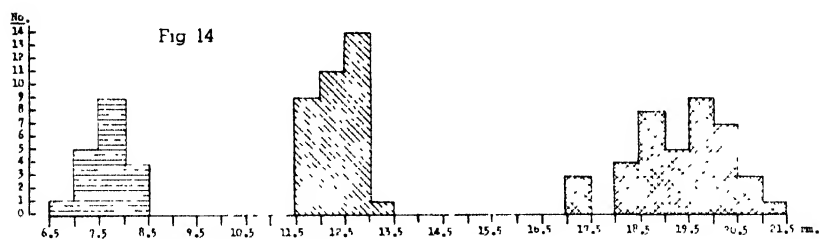
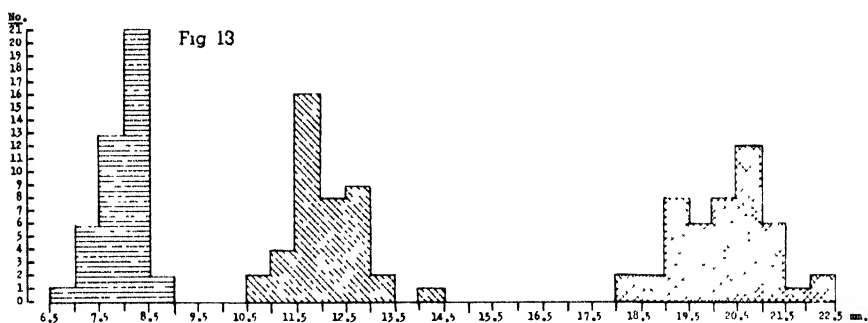
The gap between *fuliginosa* and *fortis* is much more clearly defined than that between *fortis* and *magnirostris*, and one is rarely in doubt as to whether or not a specimen should be considered as a large *fuliginosa* or a small *fortis*. The measurements of a few specimens formerly named *G. harterti* are given in the table of questionable specimens, and, in addition to these, the populations on the extremely small islands of Daphne and Crossman seem to be intermediate in character between *fuliginosa* and *fortis*. Swarth (1931, p. 163) considered the Daphne birds to be small *fortis*, but although the largest specimens resemble *fortis* on James, the average for the population is much smaller than for *fortis* found anywhere else. Some of them come very close to *fuliginosa*. The Crossman population averages smaller than that of Daphne. The larger specimens resemble the Daphne birds, while the smaller birds seem



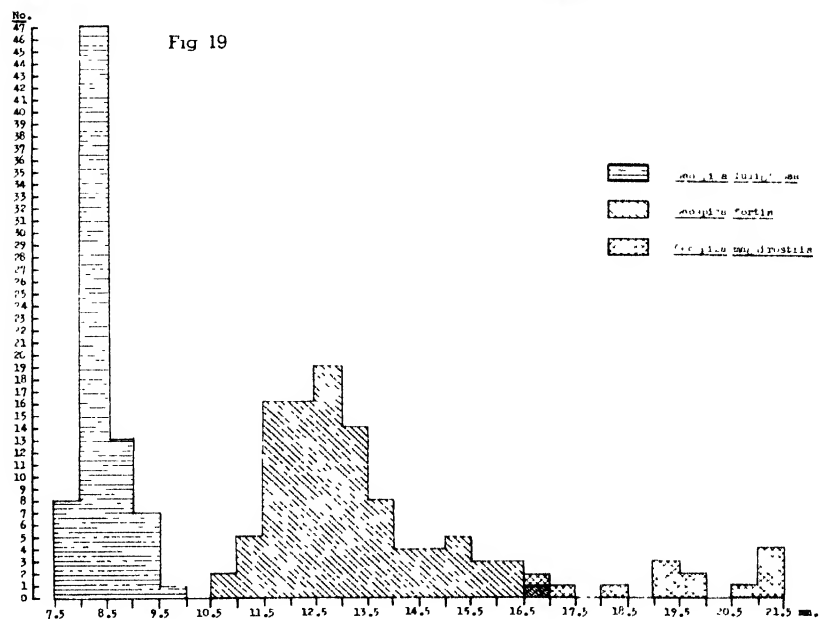
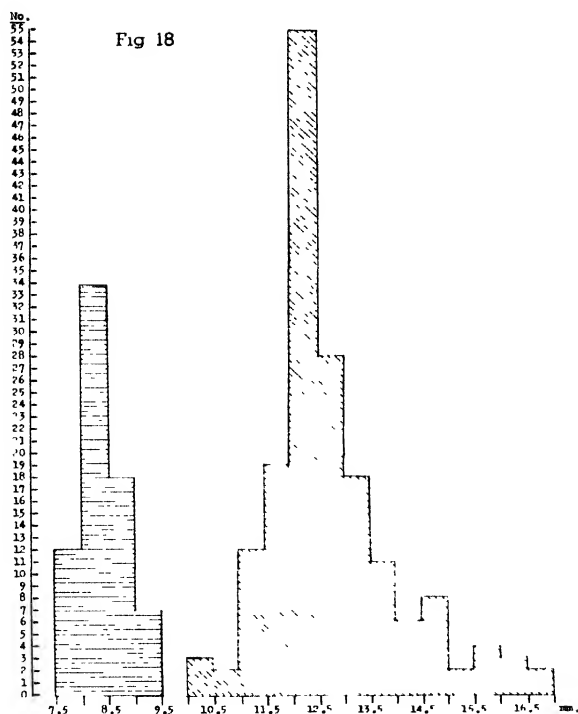
Variation in length of culmen of males. Fig. 5, Abingdon;  
Fig. 6, Bindloe; Fig. 7, James; Fig. 8, Daphne.



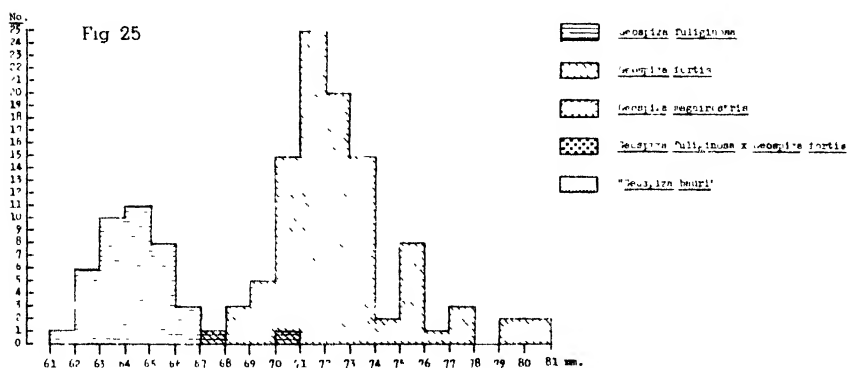
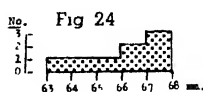
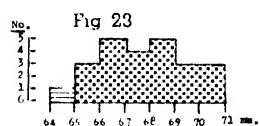
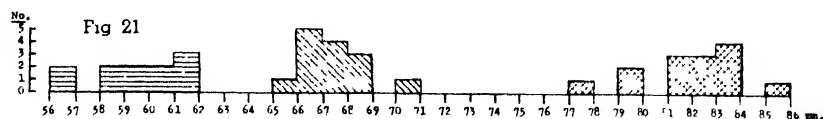
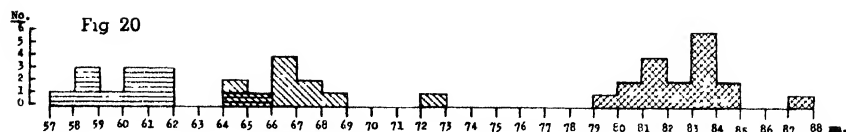
Variation in length of culmen of males. Fig. 9, Indefatigable;  
Fig. 10, Crossman; Fig. 11, Chatham; Fig. 12, Charles.



Variation in depth of bill of males. Fig. 13, Abingdon; Fig. 14, Bindloe; Fig. 15, James; Fig. 16, Daphne; Fig. 17, Crossman.



Variation in depth of bill of males. Fig. 18, Charles;  
Fig. 19, Indefatigable.



Variation in wing length of black males. Fig. 20, Abingdon; Fig. 21, Bindloe; Fig. 22, James; Fig. 23, Daphne; Fig. 24, Crossman; Fig. 25, Charles; Fig. 26, Indefatigable.

quite typical of *fuliginosa*. The most probable explanation is that these forms have originated from a cross between *fuliginosa* and *fortis*. One might expect hybridization on such tiny islands where wandering birds might find few or none of their own species available.

The histograms, Text Figs. 5-26, also show that on different islands the specific limits occur in a different place. For instance, specimens of male *Geospiza* with a culmen of 14 mm. are *magnirostris* on Bindloe or Jervis, but *fortis* on Chatham or Charles, and on Indefatigable might be either. Also, males with culmen 10 mm. are *fuliginosa* on Chatham but *fortis* on Charles. As regards depth of bill, *fuliginosa* and *fortis* show no overlapping, and for *magnirostris* and *fortis* there is much less overlapping in this measurement than for that of culmen from nostril. Males with a depth of bill of 16 mm. on Jervis and 16.5 mm. on Indefatigable are *magnirostris*, whereas on Charles they are *fortis*. In wing length, black males with a wing of 64-66 mm. on Abingdon are *fortis*, but on all the southern islands they are *fuliginosa*. Black males with a wing of 79 or 80 mm. on Abingdon, Bindloe, or Jervis are *magnirostris*, but on Charles are *fortis*. In all these instances, other characters make identification of the species certain, but in other cases such as *G. bauri*, identification is much less positive.

*Geospiza fuliginosa*, *fortis*, and *magnirostris* differ from each other not only in actual size of wing and bill, but in relative length of bill as compared with length of wing, and in relative depth of bill as compared with its length. The larger species have relatively longer and deeper bills. This suggested that the differences in proportions of these parts in these three species might be due simply to allometric ratios between these parts and general body size (see Huxley, 1932). In this instance, one would expect similar allometric relations to hold within each species. To test this possibility Text Tables 10 and 11 were prepared.

From these tables it will be seen that within each species there is, with increasing wing length, no increase in the proportion of length of bill to length of wing; likewise, with increasing length of bill, there is no increase in the ratio of the depth of bill to its length. In each species, regardless of the size of the individual, the ratio between culmen and wing and between depth of bill and culmen is approximately constant. There is no tendency whatever toward an allometric relation of these parts.

Table 16

Ratio of Culmen to Wing in Black Male Geospiza fuliginosa, fortis and magnirostris

No.	Wing	Mean	Culmen Range	$\sigma$	Ratio
<u>Geospiza fuliginosa</u> (Chatham, Charles, N. and S. Albemarle)					
29	60 - 62 (61.8)	8.58	7.7-9.9	.427	.139
52	63	8.42	7.6-9.8	.534	.134
68	64	8.52	7.4-10.2	.497	.133
44	65	8.59	7.7-9.9	.525	.132
26	66	8.77	7.9-10.1	.567	.133
6	67 - 70 (67.7)	8.90	8.3-9.5	.587	.132
<u>Geospiza fortis</u> (Chatham, Charles, N. and S. Albemarle)					
9	66 - 68 (67.4)	10.89	10.1-11.8	.515	.162
9	69	11.38	10.4-12.3	.645	.165
27	70	11.35	10.7-12.1	.435	.162
44	71	11.58	10.1-13.9	.655	.163
38	72	11.59	10.7-13.2	.644	.161
28	73	11.74	10.3-13.5	.726	.161
17	74	12.33	11.3-13.4	.518	.167
26	75	12.40	10.8-14.0	.875	.165
12	76	12.78	12.1-13.6	.483	.168
18	77 - 80 (78.0)	12.78	11.9-14.1	.614	.165
<u>Geospiza magnirostris</u> (all)					
9	77 - 80 (78.9)	15.20	14.0-16.5	.770	.193
13	81	15.36	14.2-16.8	.670	.190
13	82	15.41	14.0-16.0	.559	.186
17	83	15.72	14.5-17.3	.680	.189
13	84	16.05	14.7-17.7	1.055	.191
13	85	16.41	15.9-17.2	.355	.189
14	86	15.96	15.1-17.2	.673	.186
10	87	15.82	14.2-16.8	.798	.182
7	88 - 90 (88.6)	16.39	15.1-17.4	.773	.185
3*	90 - 94 (91.3)	18.43	18.0-18.9	.451	.202*
<u>Geospiza fortis</u> x <u>fuliginosa</u> ? (Daphne)					
12	65 - 67 (66.08)	10.33	9.2-11.2	.665	.156
11	68 - 70 (68.82)	10.53	9.9-11.3	.476	.155
<u>Geospiza fortis</u> x <u>fuliginosa</u> ? (Crossman)					
8	63 - 67 (65.60)	9.36	8.0-11.2	1.049	.143

\* Darwin's black males.



Table 11

Ratio of Depth of Bill to Culmen in Male Geospiza fuliginosa, fortis and magnirostris

No.	Culmen		Depth of Bill		$\sigma$	Ratio
	Mean	Range	Mean	Range		
<u>Geospiza fuliginosa</u> (Chatham, Charles)						
13	7.52	7.2-7.7	7.70	7.1-8.3	.390	1.02
28	8.03	7.8-8.2	7.83	7.2-8.7	.398	.98
51	8.54	8.3-8.7	8.09	7.2-8.9	.410	.75
65	9.00	8.8-9.2	8.21	7.4-9.1	.355	.91
16	9.45	9.3-9.7	8.40	7.4-9.1	.489	.89
9	9.93	9.8-10.2	8.31	8.0-8.6	.215	.84
<u>Geospiza fortis</u> (Chatham, Charles)						
5	10.10	9.8-10.2	10.96	10.1-11.9	.856	1.09
12	10.48	10.3-10.7	11.47	10.7-12.1	.446	1.09
54	11.04	10.8-11.2	11.89	10.2-13.2	.567	1.08
55	11.44	11.3-11.7	12.25	10.8-13.6	.612	1.07
72	12.02	11.8-12.2	12.80	11.1-15.3	.877	1.07
25	12.48	12.3-12.7	13.43	12.0-14.8	.750	1.08
33	12.93	12.8-13.2	14.44	12.1-16.0	1.032	1.12
10	13.48	13.3-13.7	14.57	13.1-15.4	.787	1.06
6	14.03	13.8-14.2	14.85	13.6-16.0	1.035	1.06
<u>Geospiza magnirostris</u> (all)						
11	13.97	13.8-14.2	17.34	15.8-19.4	.977	1.24
13	14.50	14.3-14.7	18.04	16.3-19.4	.978	1.24
43	15.01	14.8-15.2	18.92	16.8-21.6	1.066	1.26
40	15.47	15.3-15.7	19.56	18.0-21.4	.865	1.26
55	15.96	15.8-16.2	20.23	18.2-22.3	.963	1.27
32	16.43	16.3-16.7	20.85	18.9-22.5	.831	1.27
19	16.96	16.8-17.2	20.94	19.5-22.9	.917	1.23
7	17.43	17.3-17.7	21.74	19.9-23.2	1.139	1.22
3*	18.43	18.0-18.9	23.67	23.6-23.7	.058	1.28*
<u>Geospiza fortis</u> x <u>fuliginosa</u> ? (Daphne)						
10	10.04	9.8-10.2	10.07	8.6-10.6	.383	1.00
6	10.60	10.3-10.7	10.93	9.7-11.9	.755	1.03
9	11.09	10.8-11.3	10.97	10.4-11.5	.378	.99
<u>Geospiza fortis</u> x <u>fuliginosa</u> ? (Crossman)						
11	9.43	8.4-11.2	9.55	8.3-10.4	.802	1.01

\* Darwin's black males.

The tables therefore show that the ratio of culmen to wing, and of depth of bill to culmen, provide a criterion for distinguishing the three species. However, it must be noted that among the individuals of each species, the variations in these ratios are large. For instance, on Charles the ratio of depth of bill to culmen in *fortis* varied between .92 and 1.32, that is from typical values for *fuliginosa* up to typical values for *magnirostris*. Similar considerations apply to the other species, as can be seen by inspecting the range in culmen for each particular wing length, and the range in depth of bill for each length of culmen, given in Text Tables 10 and 11. Hence, these ratios do not form a satisfactory method for identifying any particular specimen, but are only valuable when a series can be compared.

I have also included in these tables the same ratios for the unusual Daphne and Crossman populations and for the single male specimen of *Geospiza bauri*. It will be noted that the ratios for the Daphne and Crossman populations tend to be intermediate between those for *fuliginosa* and *fortis*. This provides further evidence for the hybrid origin of these forms. The specimen of *G. bauri* is intermediate between *fortis* and *magnirostris* and might be either.

*Camarhynchus* species: in the species of *Camarhynchus* there is a problem similar to that presented by the three species of *Geospiza* described above. On most islands, there is a larger and a smaller species, which differ primarily in the mensural characters of bill and wing. Here also the larger species has a longer bill in proportion to wing length, and a deeper bill in proportion to its length. However, there are also small plumage differences. I have not given details, since there are too few specimens available.

On Charles, a particularly interesting situation is presented, since on this island there are three species of *Camarhynchus*. The gap between the smallest, *parvulus*, and the middle form, *pauper*, is fairly well defined, although there are two specimens which cannot be assigned to either and might possibly be hybrids. A few other specimens show a slight overlapping either in wing length, or length of culmen from nostril, or depth of bill, but never in more than one of these characters at the same time. All can be safely assigned to one or the other species. *Camarhynchus pauper* and the larger *psittacula* show a wide overlapping in length of wing and length of culmen, but apparently there is no overlapping in depth of bill, although the two species come extremely close to each

other. However, few specimens of *psittacula* are available from Charles, and further collecting is needed before an extended discussion would be justified.

There seem to be only a few other instances in birds where closely related species differ markedly from each other in size of bill but in little else. This occurs in the two species of *Nesospiza*, the endemic finch genus of the Tristan da Cunha group (Lowe, 1923, pp. 519-523), also in the West Indian finch *Oryzoborus* and in the African weaver *Pyrenestes* (Chapin, 1924). *Pyrenestes* is particularly complicated since in each of two species two sizes of bill occur, and in a third species there are three sizes of bill. The relations between these forms are not properly understood. Friedmann (1934) describes another possible instance in the hawk genus *Chondrohierax*.

#### DIFFERENCES IN VARIABILITY BETWEEN SPECIES

As may be noted from the Main Tables, the various species differ in variability, in some cases markedly, whether this is measured by the standard deviation or by the coefficient of variation. Some typical examples are set out in Text Tables 12 and 13.

Day and Fisher (1937, pp. 337-340) have recently criticized the use of the coefficient of variation, since there is no real reason for supposing that the variability should change in direct proportion to the mean. This is a valid criticism. However, as may be seen from the tables, the larger Geospizinae tend to be more variable than the smaller species. This suggests that there is some relation between size and variability as measured by the standard deviation, and that the latter is not an altogether fair means for comparison. Hence, in Text Tables 12 and 13, I have given both standard deviation and coefficient of variation, although I agree that the relation between the degree of variability and the mean size is probably not a direct one. The tables suggest that dividing directly by the mean rather overcompensates for the increase in standard deviation due to increase in mean.

A number of factors affect variability, and it seemed worth checking to see if the rule that the most abundant forms were the most variable, and the least common forms were the least variable, applied when species were compared. In Text Table 12, the species on Indefatigable have been listed in their order of abundance. The estimates of abundance are fairly reliable since they are based

Table 12

Relation between Variability and Abundance in Male *Geospizinae*

Indefatigable Island						
Species (in order of abundance)	Subjective estimate of abundance, expressed as percentage	Culmen coefficient of Variability	Depth of Bill coefficient of Variability	Wing coefficient of Variability		
<u>Certhidea olivacea</u>	47	.338	4.44		1.54	2.42
<u>Geospiza fuliginosa</u>	16	.576	4.47	.320	4.64	1.57
" <u>aculeata</u>	12	.767	5.15	.433	4.44	1.11
" <u>fortis</u>	10	.806	6.77	1.574	10.30	2.79
<u>Camarhynchus parvulus</u>	5	.443	5.91	.324	4.43	0.63
<u>Platyspiza cinerea</u>	5	.282	2.70	.338	2.75	1.26
<u>Cactus sp. pallida</u>	5	.576	3.11	.209	2.50	1.59
<u>Geospiza magnirostris</u>	2	.799	5.23	1.765	9.27	1.50
<u>Camarhynchus poiteacalis</u>	1	.597	6.19			
<u>Geospiza d. debilis</u>	1	.320	3.33	.334	3.82	1.27
Tower Island						
<u>Certhidea olivacea</u>	43	.206	2.52		0.94	1.76
<u>Geospiza difficilis</u>	43	.577	4.37	.528	4.15	1.51
" <u>magnirostris</u>	9	.599	5.63	1.17	5.74	1.42
" <u>conirostris</u>	7	.762	5.31	.956	3.8	1.96

Table 13

Relation between Variability and Specialization in Male *Geospizinae*

Species	Degree of specialization of diet	Degree of specialization of bill	Island where bred	Culmen coefficient of Variability	Depth of Bill coefficient of Variability	Wing coefficient of Variability
<i>Geospiza fuliginosa</i>	extreme specialization	very generalized	Indefatigable	.76	4.4	.57
" <i>fuliginosa</i>	generalized	specialized for seed eating	"	.50	1.77	.52
" <i>difficilis</i>	"	generalized	"	.57	4.76	3.2
" <i>difficilis</i>	"	"	Wood	.61	5.2	1.14
" <i>magnirostris</i>	"	specialized	Tower	.59	1.53	.37
<i>Camarhynchus parvulus</i>	"	generalized	"	.47	4.07	.54
" <i>parvulus</i>	"	"	"	.44	4.47	.42
<i>Geospiza cinerea</i>	partly specialized	specialized	Indefatigable	.77	4.47	.53
<i>Platyspiza cinerea</i>	specialized	generalized	"	.28	1.76	.55
<i>Geospiza pallida</i>	"	specialized	S. Albemarle	.57	1.84	.41
<i>Certhidea olivacea</i>	"	specialized	Indefatigable	.76	4.47	.57
<i>Geospiza difficilis</i>	"	specialized	Wood	.61	5.2	1.14

Note. For comparison male *Geospiza d. difficilis* Berkeley California culmen coefficient of variability 4.44 (measured), depth of bill 0.793, coefficient of variability 1.57 (80 measured), wing 0.146 coefficient of variability 1.96 (17 measured).

on serial counts and general observations made during the expedition's visit to the island. In the second part of the table, the same procedure has been adopted for Tower Island, which was also visited by the expedition. It is seen that there is no obvious relation between variability and abundance on either island, and the same applies to Chatham, for which I did not make a table. This is true whether one uses standard deviation or coefficient of variation.

Clearly abundance is not the most important factor controlling variability when different species are compared.

Another possibility is that the more specialized species, with reference to feeding habits or structure or both, are less variable than the generalized species. This is tested in Text Table 13. The degree of specialization of the bill has to be estimated subjectively, but I have based my estimates on comparisons with mainland forms. The table shows that there is less correlation between variability and specialization than might perhaps have been expected. However, the four most specialized species are among the least variable, whether this is measured by standard deviation or by coefficient of variation. The most variable forms all have generalized feeding habits.

It has often been said that the Geospizinae are made up of exceptionally variable species. From this study, however, it is clear that most species of Geospizinae are not exceptionally variable when compared with those mainland birds which have so far been investigated. Comparison may be made with *Passer domesticus* (Lack, 1940*d*), with *Junco* (Miller, 1941), and with *Lanius* (Miller, 1931). There are, however, a few forms which are extremely variable. These are: (1) *Geospiza magnirostris* and *G. fortis* on most of the larger islands and on the small islands near large islands; (2) *G. fuliginosa* on Chatham; (3) the species of *Geospiza* on Daphne and Crossman; (4) *G. conirostris*. Apart from their high standard deviations, a further indication of exceptional variability is that in the past several systematists named two forms on the same island from material which later proved to belong to one form. This occurred with *G. fortis* on Charles, Chatham, and other islands, *G. fuliginosa* on Chatham, and *G. c. conirostris* on Hood. As Swarth demonstrated, and my results fully confirm, each of these is a single but highly variable form, whose mensural characters lie on approximately normal curves with no trace of bimodality, although the bill differences between extreme individuals of one form are comparable with specific differences in some mainland groups of birds. In addition to the dimensions, the shape of the bill is also extremely variable, and this applies particularly to the three forms of *G. conirostris*.

As already suggested, the high variability of *G. magnirostris* and *G. fortis* on most of the larger islands is probably a result of the relatively large size of the populations on these islands as com-

pared with those of the smaller islands. At the same time, associated with generalized feeding habits, selection pressure as affecting the bill is probably not intense. There is the further possibility that *magnirostris* and *fortis* occasionally interbreed, since these two species possibly intergrade on Indefatigable and Albemarle. While such hybridization possibly occurs, it cannot be the cause of the high variabilities in question since:

(a) *Geospiza magnirostris* is as variable on James and Jarvis as it is on Indefatigable, but there are no grounds for assuming that it interbreeds with *fortis* on the two former islands; first, because the gap between the two species is here clear-cut, and second, because *fortis*, which is rather uncommon on Indefatigable, is stable, and not especially variable, on James.

(b) *Geospiza fortis* is slightly more variable on Charles than on Indefatigable or Albemarle, but one would expect hybridization with *magnirostris* to be much rarer on Charles than on Indefatigable and Albemarle, since *magnirostris* is not resident on Charles. One specimen of *magnirostris* is listed from Charles, but this must be a relatively rare occurrence.

(c) *Geospiza fortis* from Charles is also exceptionally variable on the small side of the mean, and there is no reason for assuming that it interbreeds with *fuliginosa*. Hence, hybridization, if it occurs at all, is not the main cause of the high variability of *magnirostris* and *fortis* on the larger islands.

*Geospiza fuliginosa* is relatively stable excepting for the high variability in culmen (but not depth of bill) on Chatham. Possibly a smaller northerly and larger southerly form of *fuliginosa* have met and merged on Chatham, but this has not been proved.

The forms of *Geospiza* on Daphne and Crossman, which are intermediate in characters between *fortis* and *fuliginosa*, are highly variable. The standard deviations are high when compared with those found in *fortis*, which has larger means, and are considerably higher than those found in *fuliginosa*. High variability is additional support for the postulated hybrid origin of these forms. If they are of hybrid origin, however, some gene elimination has presumably occurred later, since in neither form have specimens resembling larger *fortis* been collected. Another difficulty is that a few typical *fuliginosa* have been collected on Daphne. Further collecting might show that these grade into the postulated hybrid form, but there is a gap at present.

*Geospiza conirostris* presents special difficulties, since it occurs only on three small isolated islands. In such places, owing to the relatively rapid gene elimination, one would expect low, not high variability. In addition, it is the only species of the *Geospizinae* showing a markedly discontinuous distribution, since it occurs only on three outlying islands: Culpepper in the extreme northwest, Tower in the extreme northeast, and Hood in the extreme southeast of the group. This suggests that it may be an ancient species which has become extinct on the main islands in competition with later evolved forms. This does not account, however, for its high variability. Another possibility is that it is of hybrid origin.

Evidence summarized in Section I fully supports Swarth's conclusion that *Geospiza conirostris* is closely related to *G. scandens*. If it is of hybrid origin, then presumably it is between *scandens* and either *magnirostris* or *fortis*, since *conirostris* differs from *scandens* primarily in the depth of its bill. It may be noted that neither *scandens* nor *fortis* is resident on any of the islands where *conirostris* breeds; but *magnirostris* occurs with *conirostris* on Tower. *Geospiza conirostris propinqua* from Tower seems more like a *scandens*  $\times$  *fortis* than a *scandens*  $\times$  *magnirostris* cross, and furthermore shows no intergradation with *magnirostris* on Tower. Hence, if it is a hybrid, it is presumably with *fortis*. Also, four specimens from Charles and Indefatigable, intermediate in character between *fortis* and *scandens* and possibly hybrids ("*G. brevirostris*"), look somewhat like *G. c. propinqua*. As opposed to a hybrid origin for the Tower form, it should be noted that on Bindloe, the island nearest to Tower, the form of *scandens* has a deeper bill than elsewhere, and comes fairly close in appearance to small *G. c. propinqua*. Hence, one might have been evolved from the other without any hybridization. In this case, either *conirostris* is an ancient form which later gave rise to the more specialized *scandens* through the Bindloe form, or alternatively *scandens* wandered to Tower and Hood where its specialized bill was of little value, and it reverted to a more generalized form.

*Geospiza conirostris conirostris* of Hood throws little additional light on the problem. Neither *magnirostris* nor *fortis* is resident on the island. *Geospiza magnirostris* is also absent from the neighboring islands of Chatham and Charles, hence is less likely to have reached Hood than *fortis*, which is abundant on both. Actually, a number of *fortis* have been collected on Hood, and some of these

were indeed difficult to distinguish in bill from smaller *G. c. conirostris*. Thus if the latter form is of hybrid origin, it is presumably the result of a cross between *scandens* and *fortis*. In depth of bill, the larger specimens of *G. c. conirostris* far exceed the largest *fortis*, but this is not necessarily in opposition to a *G. scandens*  $\times$  *G. fortis* origin, since one does not know what characters might appear when genes of the two species are combined. In addition, there has presumably been evolution subsequent to the postulated hybrid origin.

*Geospiza conirostris darwini* of Culpepper Island is the most variable of the three forms of *conirostris*, although restricted to one extremely small, isolated island. Smaller specimens look much like *G. c. propinqua* of Tower Island; larger specimens look more like *magnirostris*. Indeed Swarth classified them as such, although the shape of the bill places them as *conirostris*. On Wenman, the only neighboring island, a typical *magnirostris* occurs. It is surprising that these two islets, which otherwise have such similar land birds, should differ so markedly in this respect, excepting on the supposition that *G. conirostris darwini* is of hybrid origin between *magnirostris* and some other species which has accidentally wandered to Culpepper. The most likely possibility is that it is a hybrid with *G. c. propinqua*, which it so closely resembles.

In summary, *G. c. darwini* appears to be of hybrid origin between *magnirostris* and *G. c. propinqua*. All evidence supports this view. The Hood and Tower forms of *G. conirostris* may be of hybrid origin; if so, it is probably between *scandens* and *fortis*. There must have been, however, subsequent gene eliminations, since neither form produces typical *scandens* nor typical *fortis*. Alternatively, *conirostris* may be an ancient form from which *scandens* later evolved, the Bindloe form showing an intermediate stage. However, this does not explain the high variability of *G. conirostris*. Also, *conirostris* may have evolved from *scandens*, independently on Hood and Tower islands, by acquiring more generalized feeding habits and bill, and increasing in variability.

#### INTER-ISLAND WANDERING

In Text Table 14 all known instances are summarized. Detection of inter-island wandering is possible only when a specimen is collected at sea or on an island where that species or island race is not resident. Most species occur on nearly all islands, and most species are not divided into definitely recognizable island races.



Table 14

Geospizinae which have Strayed from One Island to Another

Museum	Number	Species	Sex	Collected on	Presumably came from:
U.S.N.M.	115905	<u>Geospiza magnirostris</u>	P ♂	Charles	Indefatigable or S. Albemarle
C.A.S.	5465	" <u>fortis</u>	S ♂	Wenman	Albemarle (Too large for the form on Abington, Hindloe or James.)
C.W.	12379b	" "	B ♂	Tower	Abington, Hindloe or James
C.A.S.	various	" "	8 J W's, 7 ♀♀	Hood and Gardner	Charles or Chatham
Rothschild Coll.	517705	" <u>scandens</u>	S ♂	James	Hindloe
C.A.S.	7191	" "	1 ♂	At sea 20 miles south of Indefatigable	Charles or Indefatigable
Rothschild Coll.	517049	" <u>c. conirostris</u>	♀	Gardner near Charles Hood	
Rothschild Coll.	517986	<u>Camarhynchus psittacula</u>	1 ♂	Chatham	Indefatigable or Barrington
Rothschild Coll.	517985	" "	♀	Chatham	Indefatigable or Barrington
C.A.S.	7904	" <u>parvulus</u>	♀	Wenman	
C.A.S.	7943	" "	♀	Wenman	
C.A.S.	7629	<u>Ceospiza pallida</u>	♂	Charles	Indefatigable

\*B-black plumage, P-partly black plumage; ♀-streaked plumage

Note. All the above specimens, except those of Geospiza scandens, were collected on islands where so much other collecting has been done that the species can safely be said not to be resident there. Of the Geospiza scandens, one was actually taken at sea and the unusual specimen from James was clearly not of the type resident on James, but was indistinguishable from Hindloe specimens.

Some other specimens were perhaps stragglers, but the evidence is not conclusive: four Geospiza fuliginosa from Wenman, one Geospiza d. debilirostris from S. Albemarle, several Camarhynchus affinis (') from James, Jervis and Seymour, and possibly two Camarhynchus parvulus from Abington. From their measurements, three other Geospiza scandens may also be wanderers, as each is well outside the normal limits to the size of bill on the island on which they occurred. Details are as follows:

Stanford Coll. 4650, 1 ♂, from Seymour, measured 17.4, 10.2, 68, so perhaps came from James. Rothschild Coll. 51798b, 1 ♂, from Indefatigable, measured 13.6, 8.5, 68, so perhaps came from James. C.A.S. 7376, ♀, from Jervis, measured 13.1, 11.2, 69, so possibly came from Abington or Hindloe.

Gifford (1919, pp. 230-231) also gives four records of Geospiza fortis seen at sea at varying distances from the land.

Hence, most inter-island wandering will escape detection. Despite this, there are a number of records showing that inter-island wandering must be not uncommon, an important conclusion in relation to various discussions in Sections V and VI.

## SECTION VI. GENERAL EVOLUTIONARY PROBLEMS

In the preceding five sections, the main facts concerning variation among the Galapagos finches have been described. In this final section, some of the more theoretical aspects will be considered. To summarize very briefly, the Geospizinae are almost unique among endemic land birds of oceanic islands in that there is more than one species on each island. The main genera show an adaptive radiation. The species within the genera differ primarily in size and shape of bill, and some are extremely similar. Some show minor plumage differences, but the main plumage variation is a tendency to lose the male secondary sexual plumage, and, in this, closely related species resemble each other. A few forms are quite variable in size, but as a rule most of them are as stable as typical mainland birds. Most species are not segregated either by habitat or breeding season.

### PREVIOUS VIEWS

Since the time of Darwin, the Geospizinae have been the subject of considerable theoretical discussion. In recent years, several views have been put forward to account for their remarkable type of speciation. Lowe (1936, p. 320) follows Lotsy's views on certain plant groups in stating that the Geospizinae are "a swarm of hybridization segregates." Rensch (1933, pp. 37-38) considers that in almost every instance the first step in the formation of a species in birds is through geographical isolation leading to the differentiation of a subspecies. With continued isolation, the segregated subspecies becomes so different that, if it eventually meets again the form from which it diverged, it no longer interbreeds. Rensch was evidently much puzzled to understand how the Geospizinae could fit into such a scheme, and although he does suggest how the species might have evolved through geographically isolated forms, he classifies them under "Nicht-geographische Typen der Artbildungen." Stresemann (1936) is the only investigator to suggest that the evolution of the Geospizinae has not differed fundamentally from that of other avian species, namely that they have evolved through geographically isolated forms, which later met again but kept segregated.

## HISTORY OF THE ISLANDS

Before proceeding further, the geological history of the Galapagos must be considered, and in particular the problem of land bridges. Darwin, Wallace, and other early workers concluded that the islands were oceanic; that is, that their fauna resulted from chance colonization over the sea, and did not arrive via a land bridge. Baur (1891) was the first to suggest that the Galapagos were once connected by land with America. (See Scharff, 1912, pp. 295-335, for a summary of this view.) Recently Swarth (1934) has summarized the arguments in favor of an oceanic origin.

All the evidence is in favor of the supposition that the Galapagos are oceanic so far as birds are concerned. Otherwise, it is almost inconceivable that so few species of land birds should occur on the islands, especially in view of the many favorable habitats that exist there, varying from coastal thorn and *Opuntia* to humid forest and fern and grassy uplands. Only six passerine forms and one cuckoo are found, a number considerably smaller than that which has reached many of the Polynesian Islands situated a comparable distance from the mainland. The latter lie in the trade wind belt, whereas the Galapagos are in an area of calms. This corroborates the oceanic origin of the birds, since it makes the Galapagos relatively less open to colonization by aerial forms.

Furthermore, when compared with each other, the six passerine forms and the cuckoo show a very marked degree of difference from mainland forms. This seems obviously correlated in part with a different time of arrival on the islands, another argument in favor of an oceanic origin. Examples of the successive stages in differentiation among the land birds are: (1) the cuckoo (*Coccyzus melacoryphus*) seems identical with a mainland form, and therefore presumably arrived recently; (2) the warbler (*Dendroica petechia aureola*), which also occurs on Cocos Island, and the martin (*Progne m. modesta*) are subspecies of mainland species; (3) the flycatcher (*Myiarchus magnirostris*) is a species of a mainland genus and is not obviously related to any mainland species. Hellmayr (1927, p. 187) placed it in a genus by itself, *Eribates*, but this hardly seems justified. In appearance, call notes, and field habits it certainly comes very close to the ash-throated flycatcher (*Myiarchus cinerascens*) which I observed in California. (See also

Swarth, 1931, pp. 85-86.) (4) The Galapagos vermilion flycatcher (*Pyrocephalus*) is less differentiated than *Myiarchus magnirostris* in that it is closely related to a mainland species, *P. rubinus*. In another way, however, evolution has proceeded further, in that three island forms have been separated on the Galapagos. Hellmayr rightly considered, in my opinion, the Galapagos forms to be subspecies of *Pyrocephalus rubinus*. Swarth considered them separate species, but they are obviously geographical forms of *P. rubinus* and are not very different. (5) The Galapagos mockingbirds (*Nesomimus*) have been placed in a distinct genus. They are obviously related to the mainland genus *Mimus*, although there is no particular species with which they can be linked. *Nesomimus* has developed into distinct forms on all the main Galapagos Islands, and in some cases these are so distinct as to merit specific rank. (6) Finally, the Geospizinae arrived so long ago that they have had time to develop into widely divergent genera and species, greatly different from the ancestral (? West Indian) stock from which they originated. Mayr (1940, p. 267) gives a similar table for the various stages in differentiation shown by the birds of Biak and Rennell islands (both oceanic islands).

The main argument in favor of a former land bridge from the Galapagos to the mainland is the presence of several terrestrial reptiles. Representatives of each of these could have been carried to the islands during a hurricane or on driftwood. If they did cross to the islands on a land bridge, then it was in very early (? Mesozoic) times, and this land bridge disappeared before the period when birds could make use of it.

Except where they have been exterminated by man, all the main Galapagos reptiles are found on all the main islands, and so are rodents of the genera *Oryzomys* and *Nesoryzomys*. This strongly suggests that the main islands, possibly omitting Culpepper and Wenman, were connected with each other (although not necessarily with the mainland) at some time in the past, since otherwise it is almost inconceivable that each island should have been separately colonized. On Indefatigable, two species of *Nesoryzomys* (cf. Osgood, 1929, and Orr, 1938) and two species of the snake, *Dromicus* (Van Denburgh, 1912*b*), are found, hence possibly there have been two separate occasions when Indefatigable was connected with other islands. This, however, does not apply to islands other than Indefatigable, since, on all the others that are inhabited by rodents

of either of the genera *Oryzomys* or *Nesoryzomys*, only one species per island occurs. The same is true of the snake, *Dromicus*. The gecko, *Phyllodactylus* (Van Denburgh, 1912a), and the lizard, *Tropidurus* (Van Denburgh and Slevin, 1913), are represented by only one species on each island, including Indefatigable, so there may be some other explanation for the two Indefatigable *Nesoryzomys* and *Dromicus*. The tortoise, *Testudo*, is represented by a separate form on each main island, and by five forms on Albemarle (Van Denburgh, 1914). There are five main mountains on Albemarle; each mountain is populated by one of the five forms of tortoises present on the island. This may indicate fairly recent elevation of the land, uniting these mountains which were formerly islands. Dall and Oschner (1928) report both Pleistocene and Tertiary (probably Pliocene) fossil mollusca on raised beaches on various Galapagos Islands. From the evidence above, it is clear that insular conditions in the Galapagos have varied considerably in the past. Shepard and Beard (1938) have provided evidence for large submarine canyons off the coast of California and also in many other parts of the world, which are a further indication of big changes in sea level. The depths involved are more than sufficient to unite all of the Galapagos Islands, but there is no need to suppose that the Galapagos have been united with the mainland during or since the time at which the present avifauna colonized them.

Since birds can fly across the sea, the Geospizinae are not of as much interest as the mammals and reptiles in studying the land connections between the islands. However, it is well to remember, in considering the evolution of the Geospizinae, that conditions of isolation in the past were probably very different from what they are today.

#### COMPARISON OF THE DIFFERENT GALAPAGOS ISLANDS

Conditions of isolation are clearly different on the various islands of the Galapagos. In Text Table 15, the size of each island and the degree of isolation are indicated. (For details of islands see Frontispiece map, and Text Table 1 in Introduction.) Also included in this table are the total number of resident species of Geospizinae and the total number of endemic forms on each island (for details see Text Table 2 in Section I). For the endemic forms, two divisions are made: forms found only on a particular island, and forms found on that island and the neighboring one. This is

necessary since in two instances a pair of islands are near each other but separated from the rest. These pairs are considered together at the end of the table.

TABLE 10

Distribution of *Geospizinae* on Galapagos Islands

Island	Position	Size	Number of resident species	Number of endemic forms	Number of forms found on only one other island
Culpepper	Extremely isolated	Extremely small	3	1	2
Wenman	Extremely isolated	Extremely small	3	0	2
Tower	Isolated	Small	4	2	1
Hood	Isolated	Moderately small	3	2	-
Abinndon	Moderately isolated	Moderate	8 (9)*	-	3 $\frac{1}{2}$ **
Rindloe	Moderately isolated	Moderate	7	-	2 $\frac{1}{2}$ **
Chatham	Moderately isolated	Large	7	3 $\frac{1}{2}$ **	-
Charles	Moderately isolated	Moderately large	8	2	-
Barrington	Near central	Moderately small	7	1	-
James	Central	Large	10	$\frac{1}{2}$ **	1
Indefatigable	Central	Large	10	-	1
Albemarle + Marborough	Central west	Very large	11	2	-
Jervis	Central	Small	9	-	-
Duncan	Central	Small	9	-	-
Taken in pairs					
Culpepper + Wenman	Extremely isolated	Extremely small	4	3	-
Abinndon + Rindloe	Isolated	Moderate	8 (9)*	2 $\frac{1}{2}$ **	1

\* Camarhynchus parvulus is doubtfully resident on Abinndon.

\*\* The partial differentiation of Geospiza scandens has been reckoned as  $\frac{1}{2}$ .

Note This table is based on the data in Table 1, Section I.

The table shows that, as might be expected, the large central islands of Indefatigable, James, and Albemarle have a greater number of resident species than any others, while the small central islands of Jervis and Duncan have nearly as many. Furthermore, the percentage of endemic forms is smaller on these islands than on any others. At the other extreme, Culpepper, Wenman, Tower, and Hood show that the smallest and most isolated islands have the smallest number of resident species, but, at the same time, the largest percentage of endemic forms. Thus two out of the three

Table 14

## Measurements of Specimens of Questionable Identity

Of or between Geospiza magnirostris and Geospiza fortis

Museum	Number	Island	*Sex	Culmen Length	Bill Depth	Wing Length	Here assigned to:
B.M.	75.4.2.18	Hindane	♀	13.8	16.4	74	<u>magnirostris</u>
Rothschild Coll.	516961	"	♀	13.4	15.4	73	unassigned-like <u>Geospiza harrisi</u>
B.M.	85.12.14.293	"	?	13.0	15.7	78	" " " "
Rothschild Coll.	17184 James	"	B ♂	13.8	16.1	81	" " " "
"	" 517122	"	♀	13.7	15.3	78	" " " "
"	" 517123	"	♀	14.0	15.3	75	" " " "
M.C.Z.	65747	"	♀	13.8	15.5	74	" " " "
C.A.S.	5337 Jervis	"	B ♂	14.0	15.8	79	<u>magnirostris</u>
C.A.S.	5481 Seymour	"	S ♂	13.3	17.3	73	"
"	5995	"	♀	14.9	17.6	73	"
"	6164	"	♀	14.0	15.3	77	"
"	5223 Indefatigable	"	B ♂	13.8	16.6	79	<u>fortis</u>
"	5336	"	B ♂	13.7	16.0	78	"
A.M.N.H.	292387	"	B ♂	13.5	15.4	76	"
Rothschild Coll.	517126	"	P ♂	12.9	15.4	75	"
C.A.S.	6780	"	P ♂	12.6	16.2	75	"
"	5550	"	S ♂	14.3	16.3	75	<u>magnirostris</u>
A.M.N.H.	443039	"	S ♂	14.0	16.3	76	"
B.M.	99.9-1.175	"	S ♂	13.8	15.8	74	<u>fortis</u>
Rothschild Coll.	516951	"	♀	14.1	15.8	--	<u>magnirostris</u> (?)
"	" 516929	"	♀	13.9	15.7	75	" "
A.M.N.H.	292385	"	♀	13.7	15.3	77	<u>fortis</u>
U.S.N.M.	189233	N. Albemarle	P ♂	13.1	15.4	74	"
Rothschild Coll.	517140	"	S ♂	13.3	15.6	75	"
B.M.	99.9-1.156	"	♀	13.7	16.7	75	<u>magnirostris</u>
C.A.S.	5340	S. Albemarle	B ♂	13.5	15.7	78	<u>fortis</u>
Stanford Coll.	4355	"	B ♂	12.7	15.7	78	"
"	" 5150	"	B ♂	13.0	15.6	76	"
C.A.S.	5446	"	P ♂	13.1	15.8	75	"
"	5488	"	S ♂	14.5	16.5	76	<u>magnirostris</u>
"	5551	"	S ♂	14.4	16.3	77	"
"	5508	"	B ♂	14.0	15.3	77	<u>fortis</u>
Rothschild Coll.	517047	"	S ♂	13.0	15.3	74	"
C.A.S.	6196	"	♀	12.9	15.0	76	"
"	6320	"	♀	13.2	15.2	79	"
C.A.S.	6036	S. Albemarle	♀	13.9	15.8	74	<u>fortis</u> (?)
"	(new 1939)	Chatham	♀	12.9	16.2	78	"
Rothschild Coll.	517091	"	♀	13.2	16.4	77	"
C.A.S.	6011	"	♀	13.8	16.0	75	"

Note Except for "Geospiza harrisi" almost all the above specimens have been assigned by me to one or the other species - not always according to the label on the specimen, and I differ even from Swarth over C.A.S. 6196 and 6320, females from S. Albemarle. For those specimens assigned to magnirostris but within the range of fortis, I have been especially influenced by the length of the whole culmen (measurements not published, but available in the deposited measurements).

\* B-black plumage, P-partly black plumage, S-streaked plumage

Table 16 (continued)

Of or between Geospiza fortis and Geospiza fuliginosa

Museum	Number	Island	*Sex	Culmen Length	Bill Depth	Wing Length	Here assigned to
Rothschild Coll.	517667	Chatham	B ♂	9.6	10.2	69	unassigned (type <u>Geospiza harterti</u> )
M.C.Z.	134650	Charles	B ♂	10.1	10.1	67	<u>fortis</u>
B.M.	55.12.14 297	"	B ♂	9.8	--	68	" (labelled <u>dentirostris</u> )
Rothschild Coll.	517663	Mood	B ♂	8.8	10.2	65	probably <u>fuliginosa</u> but not included in main tables
"	"	517661 No locality from data is E. Albemarle	S ♂	9.3	10.8	65	intermediate, referable to Crossman form obtained there
"	"	517662 E. Albemarle	S ♂	9.7	10.7	67	intermediate, referable to Crossman form obtained there
B.M.	99.9-1.293	Duncan	?	9.2	9.8	64	<u>fuliginosa</u>
B.M.	55.12.19.176	?	?	10.6	10.7	68	<u>fortis</u> (type <u>Geospiza dentirostris</u> )

Of or between Geospiza fortis and Geospiza d. debilirostris

Rothschild Coll.	517702	James	B ♂	11.4	10.0	69	unassigned
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"Geospiza nebulosa"

B.M.	37 2 21 400	?	?	10.9	10.1	72	type-extinct form of <u>Geospiza difficilis</u> ?
B.M.	55 12.19.20	?	?	11.2	10.2	71	type-extinct form of <u>Geospiza difficilis</u> ?

Between Geospiza fortis and Geospiza scandens

C A S.	7047	Charles	B ♂	13.0	11.0	73	unassigned
U S N A.	115920	"	P ♂	13.2	11.6	69	" -type " <u>Geospiza brevirostris</u> "
Rothschild Coll.	516928	Indefatigable		12.8	13.0	68	"
U.S.N.A.	77756	"	?	12.8	11.0	71	"

Unassigned specimens labelled Juvenal Geospiza scandens

Museum	Number	Island	*Sex	Culmen Length	Bill Depth	Wing Length	Here assigned to
Rothschild Coll.	517703	James	S ♂	11.5	8.2	67	unassigned
"	"	517815 M Chatham	?	10.7	7.8	65	"
B.M.	99.9-1.335	James	♀	11.0	8.0	67	"

Large Geospiza scandens on James

Rothschild Coll.	517705	James	L ♂	14.3	--	72	strey <u>Geospiza scandens</u> from Hindloe (not included in main tables)
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Dwarf Platyspiza crassirostris

Stanford Coll.	4469	E. Harborough	S ♂	8.6	9.8	77	<u>Platyspiza crassirostris</u> but not included in main tables
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\* B-black plumage; P-partly black plumage, S-streaked plumage



Table 16 (continued)

Apparent Camarhynchus affinis from the "wrong" islands ("Camarhynchus incertus")

Rothschild Coll.	518053	James	♂	8.5	8.6	70	<u>Camarhynchus affinis?</u>
C.A.S.	8328	"	♂	8.5	9.0	67	" "
Rothschild Coll.	518058	"	♀	8.1	--	64	" " -type <u>Camarhynchus incertus</u>
Rothschild Coll.	518059	"	♀	8.1	8.3	63	<u>Camarhynchus affinis?</u>
C.A.S.	8357	"	♀	8.7	9.0	65	" "
C.A.S.	8387	Jarvis	♀	9.2	9.0	63	" "
"	7848	Seymour	♂	8.1	8.5	62	" "

Abnormal Camarhynchus psittacula from central islands not referable to Camarhynchus affinis

M.C.Z.	65738	James	♂	9.8	8.4	67	probably juvenile <u>Camarhynchus psittacula</u>
B.M.	99.9.1.446	"	♂	10.2	9.4	70	" " <u>Camarhynchus psittacula</u>
Rothschild Coll.	518005	Jarvis	♀	10.2	9.3	67	type " <u>Camarhynchus compressirostris</u> "
C.A.S.	38009	Indefatigable	♀	8.6	9.1	67	unassigned, as juvenile

Intermediate between Camarhynchus affinis and Camarhynchus parvulus

Stanford Coll.	4310	S. Albemarle	♂	8.4	8.7	63	unassigned
" "	4313	"	♂	7.4	8.6	63	"
C.A.S.	7875	"	♀	7.9	--	64	"
"	7883	"	♀	7.9	7.3	63	"
"	7909	"	♀	7.4	7.6	64	"
"	8346	"	♀	7.9	8.0	64	"
"	7969	"	?	7.8	7.9	64	"
"	7988	"	?	7.6	8.0	64	"
"	7867	"	♂	7.0	7.5	67	<u>Camarhynchus parvulus</u> **

Intermediate between Camarhynchus pauper and Camarhynchus parvulus

Museum	Number	Island	Sex	Culmen Length	Bill Depth	Wing Length	Here assigned to:
Rothschild Coll.	518136	Charles	♂	7.8	8.7	65	unassigned
C.A.S.	8232	"	♂	8.6	7.6	66	"

## Swarth's new species

C.A.S.	7713	Charles	♂	7.85	5.4	59	<u>Camarhynchus conjunctus</u>
"	7714	"	♂	7.8	5.9	60	" "
"	8121	Chatham	♂	8.0	6.2	59	" <u>aureus</u>
"	7522	Indefatigable	♂	10.4	6.4	65	<u>Cectospiza giffordi</u>

\*B-black plumage; P-partly black plumage; S-streaked plumage

\*\*Considered intermediate by Swarth, but here considered a parvulus with unusually long wing

species on Hood are represented by endemic forms, as are two out of the four species on Tower (a third is found on only one other island), and, taking Culpepper and Wenman together, three out of the four resident species are represented by forms confined to these two islands. Charles and Chatham are two fairly large but moderately isolated islands and both have fewer species than have the central islands, although conditions of habitat, etc., seem quite as favorable. At the same time, they have a higher percentage of endemic forms. From this comparison it is clear that, although (see Text Table 14 in Section V) birds occasionally wander from one Galapagos Island to another, they find it difficult to reach the more isolated islands, so that the present geographical disposition of the islands must be an important factor in the recent evolution of the Geospizinae.

From Text Table 15, Chatham would seem more isolated for birds than Abingdon, since Chatham possesses fewer species and a somewhat higher percentage of endemic forms. This is confirmed by evidence outside the Geospizinae, since both the mockingbird (*Nesomimus*) and the vermilion flycatcher (*Pyrocephalus*) are, as compared with the central islands, more differentiated on Chatham than on Abingdon. Conditions on the two islands seem fairly similar, although Chatham is considerably larger. Both are about the same distance from the central group. Land connections do not offer adequate explanation for this since Abingdon is separated from the central islands by a greater depth of sea than is Chatham, so presumably became isolated before Chatham. The important factor is perhaps the direction of the prevailing trade wind, which is from the southeast, thus making flight of a bird from the central islands easier in the direction of Abingdon than in the direction of Chatham. Murphy (1938) correlates a number of Polynesian bird distributions with the direction of the prevailing wind, the correlation in these cases being considerably more marked than are those cited in the Galapagos. It may be noted that the trade wind does not blow from the South American mainland to the Galapagos, but re-forms some distance from the land, hence does not facilitate the dispersal of South American land birds to the Galapagos.

#### EVOLUTIONARY FACTORS AFFECTING THE GEOSPIZINAE

The most important factors affecting the evolution of the Geospizinae may be briefly reviewed as follows: (1) other species of

land birds on the islands are relatively scarce and there were probably none there when the ancestral Geospizinae arrived, hence, while there is an abundance of varied food, the Geospizinae have no, or relatively few, food competitors; (2) as mentioned in Section III, the Galapagos finches have almost no predators; (3) owing to geographical conditions, they are divided into a number of partly, but not completely, isolated populations, some of which are of very small size.

All the above-mentioned conditions favor rapid evolution. (1) There are many instances of adaptive radiation in animals which, through isolation, have found themselves with abundant and varied food and an almost complete absence of food competitors. (2) Worthington (1940) has demonstrated for the fish in East African lakes that rapid evolution and adaptive radiation are much more likely to occur in such an isolated population when predators are absent than when they are present. In lakes Albert and Rudolph, which possess large active predator fish, the Cichlidae have not evolved to nearly the same extent that they have in lakes Victoria, Kiogo, Edward, and George, in which predators are unimportant. The almost complete absence of predators of the Geospizinae on the Galapagos therefore appears significant. Owing to these factors, the intensity of selection pressure presumably has been less for the Geospizinae than for typical mainland birds, and it may be noted that Gifford (1919) and other collectors have commented on the high percentage of deformed and diseased specimens encountered. (3) A series of small and partially isolated populations forms the conditions which, as on theoretical grounds Sewall Wright (1931, 1940) concludes, are the most favorable for rapid evolution.

#### EVOLUTION OF ISLAND FORMS

There is no evidence in favor of the supposition that the differences between the island forms of each species of Geospizinae are of adaptive significance. All the Galapagos Islands are very much alike, with similar foods, and yet sometimes the populations of a species on islands only a few miles apart are significantly different. For instance, *Geospiza magnirostris* is significantly smaller on Bindloe than on Abingdon, and on Jervis than on James. The strangely irregular variations in the bill size of *G. scandens* may also be recalled. *Geospiza conirostris conirostris* is different on two islands which are less than a mile apart. Such differences are

particularly difficult to explain on adaptive grounds in forms like *G. fortis* and *G. conirostris*, which show much more marked variation between individuals on the same island than between the means of populations of different islands. Many other examples of apparently "pointless" island differences could be quoted. Similar remarks apply to those species in which the island forms show minor differences in coloration, differences which cannot be correlated with differences in habitat. This is true particularly since, as discussed in Section IV, different species do not vary in the same direction on the same island.

This problem of the differences between island forms interested Darwin considerably, and he wrote of the Galapagos finches as follows:

... But how is it that many of the immigrants have been differently modified, though only in a small degree, in islands situated within sight of each other, having the same geological nature, the same height, climate, etc.? This long appeared to me a great difficulty; but it arises in chief part from the deeply-seated error of considering the physical conditions of a country as the most important; whereas it cannot be disputed that the nature of the other species with which each has to compete, is at least as important, and generally a far more important element of success... when in former times an immigrant first settled on one of the islands, or when it subsequently spread from one to another, it would undoubtedly be exposed to different conditions in the different islands, for it would have to compete with a different set of organisms.... If then it varied, natural selection would probably favour different varieties in the different islands.

(Cf. Darwin, 1888, pp. 355-356.)

There is no evidence in favor of Darwin's suggestion. In fact, there is no evidence whatever, in any of the island forms of *Geospizinae*, that their differences have adaptive significance. In this they resemble most geographical forms which have been described in birds. There are some exceptions, such as various desert forms, whose coloration matches the desert, and which show changes parallel with alterations in the color of the desert.

The work of Sewall Wright (1931, 1940) and others has demonstrated on theoretical grounds that, provided an isolated population is sufficiently small, it will after a time become different from a neighboring isolated population, although starting with the same gene complex, without the operation of natural selection, owing to the fact that the rate of gene elimination is quicker than the mutation rate. In each population, it is partly a matter of chance which

genes are eliminated, so that each population becomes stable at a different level. Given a sufficient length of time, such differences must arise provided the populations are small and isolated, and will arise irrespective of any differences between the environments of the populations.

The theoretical views of Sewall Wright imply that the smallest and most isolated populations of Geospizinae will tend to be the most differentiated, and also the least variable. That they are the most differentiated is fully borne out by Text Table 15 and the related discussion. That the small isolated populations are the least variable is demonstrated in Section V for *Geospiza magnirostris* and *G. fortis*, which are two of the most variable species of Geospizinae. However, the latter conclusion did not seem to hold true for the other species of Geospizinae. Hence isolation and size of population are major factors in the formation of island forms of Geospizinae. By themselves, however, they are not sufficient to account for the marked bill differences, since such marked bill differences are not normally found between small isolated populations of the same species of bird. Such a decreased intensity of selection pressure is perhaps to be expected in the Geospizinae because of their very generalized feeding habits, and an almost complete absence of food competitors. It is also borne out by the wide range in individual variation in bill sometimes shown by one form on one island. Clearly it is where selection pressure is not severe that there is a greater opportunity for the type of nonadaptive evolution, suggested by Sewall Wright, to occur.

Despite the first impression of their diversity, the Geospizinae actually show less differentiation into island forms than is typical in insular birds. Thus of the eleven well-distributed species four, namely *Geospiza magnirostris*, *G. fortis*, *G. fuliginosa*, and *Platyspiza crassirostris*, are not sufficiently differentiated for me to recognize any subspecies. *Geospiza fortis* and *G. fuliginosa* show slight wing differences on Abingdon and Bindloe. Two other species, *Camarhynchus parvulus* and *Cactospiza pallida*, are each represented by only two subspecies, in each case the form on Chatham being separate from that on all the other islands. *Geospiza scandens* shows slightly more differentiation, although even here it is very incomplete. *Geospiza difficilis*, occurring on six islands, is divided into three subspecies. The other three species show marked differentiation, *G. conirostris* occurring on three islands in three

subspecies, *Camarhynchus psittacula* (superspecies) on eight main islands in four forms, and *Certhidea olivacea* on all the main islands in eight subspecies. The degree of subspecific differentiation in the Geospizinae is not so marked as in many land birds of Polynesian Islands (Mayr, 1931-33), although the various Galapagos Islands are separated from each other by distances similar to those separating the Polynesian ones. This suggests either that the present islands of the Galapagos are of relatively recent separation from each other, or that inter-island wandering is relatively much more common among several of the Geospizinae than among most small land birds of oceanic islands.

While the "Sewall Wright effect" is probably the chief cause of subspecific differences between the members of the Geospizinae, another factor may be the random nature of colonization. For instance, the population of one island may be derived from a very small and not necessarily typical sample from another island.

#### FUNCTION OF THE BILL DIFFERENCES BETWEEN THE SPECIES

Like the island forms of one species, closely related species of Geospizinae differ primarily in bill, to a lesser extent in body size, and in some, but by no means all, instances in minor plumage characters. As summarized in Section III, there is no evidence that in closely related species the bill differences are related in any way to differences in food, feeding habits, or other differences in the ways of life of the species. In particular, *Geospiza magnirostris* and *G. fortis* occupy identical habitats and seem to have identical habits and food. This also seems true of the less-studied *Camarhynchus psittacula* and *C. parvulus*. *Geospiza fortis* and *G. fuliginosa* also show no significant differences.

What then is the significance of the bill differences between closely related species? The field study suggests an answer. In courtship, the male's most conspicuous action is to feed the female, this occasionally being reduced to billing. When one bird drives off a rival, it normally comes around in front to attack, and, if the intruder still remains, it usually grips the bill of the intruder. Hence the bill features prominently in both aggressive display and courtship, that is in the two items of behavior most closely connected with pair-formation. Moreover, when a member of one species flies into the territory of the male of another species, the

latter often flies down to it as if to attack, comes around in front, and then the whole behavior simply collapses, and nothing more happens. This strongly suggests that the different species recognize each other primarily by their bill differences, and so keep segregated. Experimental evidence, based upon the reaction of live birds to stuffed mounts (described in Section II), supports this view. It should be remembered that there are usually no plumage differences between closely related species.

Lorenz (1937) has data for many birds to show that recognition of the object to which adult reactions (social, courtship, etc.) are later directed is acquired while the young are dependent on their parents. This might apply to the Geospizinae since the bill features so prominently in the feeding of the young. Fledgling members of the genus *Geospiza* beg for food from adults of several other species (see Section II), but the latter do not respond. Hence specific recognition for subsequent breeding behavior reactions may be acquired by the juvenile at this stage, but the alternative, that such recognition is inherited, must not be overlooked.

The bill differences between closely related species of Geospizinae therefore seem similar to numerous other recognition characters in birds, the precise appearance of which is, as pointed out by Lorenz (1937), unimportant provided each character is distinct from that of other species. This view is adapted to the facts as applied to the Geospizinae much better than any other. In addition to field evidence already quoted, it is worth noting that, whereas on Hood, and also on Culpepper, *Geospiza conirostris* has a deep bill, on Tower it is much less deep. On Tower this species occurs together with *G. magnirostris*, but its bill is sufficiently narrow to prevent confusion with the latter. On the other islands, where the bill of *G. conirostris* is so deep that confusion might occur, *G. magnirostris* is not resident. However, the recognition factor must not be overemphasized. First, the bill differences are not so clear-cut as are typical recognition characters in other birds. Second, it seems possible that the different species use other minute characters at close range; thus the bill difference is not the sole factor. At a distance, song is also used at times, but males do not always sing, and the songs of different species partly overlap. Third, there is the point that *fortis* on Indefatigable is so variable that, if bill differences were the sole means of recognition, one would hardly expect small *fortis* to recognize large individuals as its own species,

when at the same time it recognizes large *fuliginosa* as a different species. A parallel difficulty might occur with the larger individuals in relation to small *magnirostris*, which they more closely resemble than they do small individuals of their own species. The frequency distributions and the bill measurements in *fortis* on Indefatigable and elsewhere form an approximately normal distribution. This is evidence for believing that there is no selective mating by bill size within *fortis*, while at the same time *fortis* undoubtedly keeps separate, at least normally, from the other two species. On the northern islands this difficulty does not occur, *fortis* being well separated from the other two species. A possible explanation is that on south Albemarle and Indefatigable conditions may be in process of change at the present time. The whole situation is extremely complex.

#### THE ORIGIN OF CLOSELY RELATED SPECIES

I agree with Stresemann (1936) in the belief that the species of Geospizinae have evolved mainly through geographically segregated island forms. If two island forms become differentiated, and later one or a few individuals fly from one island to the other, there are two possibilities if these individuals persist and breed: (1) they will interbreed with the corresponding form on the other island; (2) they will keep segregated and breed among themselves. As can be seen from various contributions to "The New Systematics" (Huxley, 1940), modern geneticists seem agreed that isolation not only produces differentiation in structural characters, but also promotes intersterility, owing to changes in the gene complex. See particularly the discussion by Wright (1940); the following quotation from Muller (1940, p. 256) expresses this view: "Thus a long period of non-mixing of two groups is inevitably attended by the origination of actual immiscibility, i.e. genetic isolation." Hence if the two forms have been isolated sufficiently long for some degree of intersterility to have appeared, any factors which prevent them from interbreeding will become intensified by natural selection. Individuals of both forms in which this segregating factor was less well developed would tend to have fewer offspring, and eventually, provided there was not too much interbreeding to begin with, two segregated species would be evolved. In *Geospiza* and *Camarhynchus*, the two genera in which closely related species differ



primarily in size of bill, the island forms also differ primarily in size of bill and, as already mentioned, the species seem to recognize each other primarily by bill differences. Hence all conditions needed for the type of evolution postulated above are present. Those island forms which later met, but differentiated each other through bill differences, have remained segregated (presumably with subsequent intensification of the bill differences), while others which failed to differentiate each other have doubtless merged. Although this is not a completely satisfactory explanation, it is extremely difficult to see any other reason for the origin, and also for the persistence of the bill differences between these closely related species with their similar food requirements.

Speculation as to the origin of different forms is always dangerous because it is difficult to check, and intervening links may have died out. In two cases, however, the origin of a segregated species from a geographically isolated form seems probable. *Camarhynchus psittacula* occurs on James, Indefatigable, and Charles. On Albemarle, it is replaced by the closely similar form *C. affinis*, which differs in its smaller bill, particularly in depth, and in its more streaked plumage. On Charles, there is another *Camarhynchus* species, *pauper*, which differs from *psittacula* primarily in the same ways as *affinis*, only more markedly. This strongly suggests that *pauper* of Charles is related to *psittacula* of the central islands through *affinis* of Albemarle, while, in more recent times, after the differentiation of these forms had occurred, *psittacula* has colonized Charles from Indefatigable. Hence on Charles *psittacula* (sensu stricto) has now met *pauper*, but the two forms have remained segregated.

*Geospiza d. difficilis* (formerly called *acutirostris*) occurs on Tower Island. This species closely resembles *fuliginosa*, which is absent from Tower, differing only in its straight culmen, in its slightly longer bill, in a slight tendency for the female to be darker, and in its song. In all respects except the last, some specimens of the Chatham Island form of *fuliginosa* approach Tower *difficilis* very closely, much more so in bill than do *fuliginosa* of any other island. It is therefore not unreasonable to assume that the Tower *difficilis* originated from some large *fuliginosa* wandering from Chatham. Chatham is a long way to the south, but the prevailing wind is from this direction. If *difficilis* occurred only on Tower, it would almost certainly be classed as a form of *fuliginosa*, since the

latter species occurs on all the main islands excepting Tower (omitting Culpepper and possibly Wenman). However, on Abingdon both a small form of *fuliginosa* and also a form of *G. d. difficilis* occur. The latter is extremely similar to that on Tower, although averaging larger. *Geospiza fuliginosa* and *G. d. difficilis* keep distinct on Abingdon and are also said to have habitat differences. *Geospiza difficilis* has also spread south on to James and Indefatigable, as has *G. d. debilirostris*. *Geospiza difficilis* presumably evolved from *G. fuliginosa* via the Tower form.

In the other species, evolution is not at a stage at which one can readily elucidate their origin, since most are widespread on all the main islands. One species, *Cactospiza heliobates*, has a very restricted distribution, but its connection with *C. pallida* is very obscure. The peculiar characteristics and distribution of *Geospiza conirostris* have been discussed in Section V. From studying Swarth's work, one might suppose that, starting in the north as a small form, *Geospiza fortis* moved south, gradually becoming larger, and then, on south Albemarle, gave rise to a larger form which became segregated as *G. magnirostris*; the latter then moved north again, gradually becoming larger and thus increasing the difference between the two species. The trends in the two species, however, are not as regular as implied by Swarth (see discussion in Section V). In addition, too few specimens of *magnirostris* have been collected on the critical islands of Indefatigable and particularly Albemarle, for conclusions to be based on them. I regard such an evolution as possible, but unlikely.

In summary, there seems no reason to believe that the species of Geospizinae have evolved in some quite unusual way. The facts are explicable on the view that they have evolved through geographically isolated forms, which remained segregated when they met, that is that their method of speciation is the one which Rensch (1933) concludes is much the most common in birds. Rensch cites *Parus major* and *P. minor*, and Ticehurst (1938, pp. 11, 17, 21-22) mentions *Phylloscopus plumbeitarsus* and *P. viridanus*, two examples of species which clearly have evolved via geographically isolated subspecies. Stresemann (1931), Salomonsen (1931), and Rensch (1934) refer to instances among closely related species of European birds which were isolated geographically for a period during the Ice Age and later met. Mayr (1940, p. 272) gives examples from *Larus* and *Pernis*.

## HYBRIDIZATION

While two forms originally isolated geographically might remain segregated when they later met, an alternative possibility is that they might hybridize. In some instances, this might result in a form sufficiently distinct to give rise to a new species. Lowe (1936) regards such hybridization as the main method of species formation in the Geospizinae. Positive evidence in favor of this is extremely scanty, but, as discussed in Section V, *G. conirostris darwini* of Culpepper is probably of hybrid origin between *G. conirostris propinqua* and *G. magnirostris*, and the form of *Geospiza* on Daphne and Crossman is probably a hybrid between *G. fortis* and *G. fuliginosa*. Incidentally, if the latter case has been correctly interpreted, it is an instance of two species occurring together over most of their range without interbreeding, but interbreeding in two isolated localities. Moreover, *G. conirostris propinqua* and *G. magnirostris* do not interbreed on Tower. Such instances seem rare in birds; Meise (1936b) found that *Passer domesticus* and *P. hispaniolensis* normally kept separate, but freely interbred in a few areas. This, however, was correlated with a habitat difference between the two species, and only where this habitat difference disappeared did the two species interbreed. In other animal groups, the species of *Patella* discussed by Fischer-Piette (1938) seem somewhat similar, in that they keep distinct in some areas and merge in others. There are of course numerous examples among birds where species normally isolated geographically interbreed when they meet, but the species referred to above normally occur in the same geographical region.

Some writers have greatly exaggerated the extent to which hybridization occurs among the Geospizinae. Beebe (1924) evidently considered it common, but had no real evidence. Swarth (1934) gives the impression that the boundaries between the species are relatively fluid, and even goes so far as to say that all the different Geospizinae might almost be classed in the same species. It is true that the species of Geospizinae are not quite so sharply separated from each other as typical mainland species in which there are normally no indeterminable specimens. Such indeterminable specimens of Geospizinae are, however, relatively rare; almost all specimens can be accurately identified, and, in three and one half months' field work, we found no instances of hybridization even

though we made special effort to look for such. The species of Geospizinae are certainly segregated to nearly the same extent as mainland birds, and the apparent overlapping may be solely in characters and not due to interbreeding. Alternatively, the indeterminate specimens may be the result of hybridization. *Camarhynchus aureus* and *conjunctus* are thought to be inter-generic hybrids, since they are intermediate in appearance between *Certhidea olivacea* and *Camarhynchus parvulus*. However, the field study showed that these two genera are so far apart that hybridization between them is most unlikely. It cannot, of course, be ruled out, especially when one remembers that mainland species do hybridize occasionally, as for example *Carduelis carduelis* and *Chloris chloris* (Meise, 1936a). If such hybridization occurred a number of times, either between two genera or two species, and the offspring were inter-fertile, one can see how a new species might be formed. There is no evidence, except that noted above, that this has actually occurred. It might, however, be difficult to detect, especially if one or both of the parent species had later become extinct.

Where a species is only slightly differentiated on two islands and individuals from one island fly to the other, interbreeding will very probably occur, and, if this is regular, it will increase the variability of the island form, but will presumably have no other effect. The variable form of *G. fuliginosa* on Chatham is perhaps to be explained in this way, and possibly this also applies to some of the variable forms of *G. fortis*. More definite examples of racial hybridization are given by Mayr (1932b, 1932c) for species of *Pachycephala* in Polynesia. In particular, *Pachycephala pectoralis whitneyi* is a hybrid race between two others, *dahli* and *bougainvillei*, and has a high individual variation between the two parent races; being insular it can be separately named. Mayr (1938) gives another case in *Megapodius*.

In brief, hybridization may have played a very minor part in the speciation of the Geospizinae, either through two forms, differentiated through long isolation, meeting and interbreeding to produce a new form, or through hybridization on very small islands of species which normally keep distinct. There is no positive evidence for the former, and the latter occurs rarely.

### *PARTIAL ISOLATION THE KEY FACTOR*

Each of the methods of speciation discussed is closely correlated with the existence of a number of islands which are both sufficiently isolated for forms to become differentiated on them, and at the same time sufficiently close together for occasional movements to occur from one island to another. If, as seems likely, there have been marked changes in sea level since the arrival of the *Geospizinae* on the Galapagos, it is not necessary to assume that movement between the islands has been possible the whole time. It may thus have been much easier at certain periods than at others.

Some authors have stated that the exceptional evolution of the *Geospizinae* is correlated with their possessing a much greater tendency to vary than most birds, by which presumably is meant a much greater mutation rate. So little is known about mutation rates that such a generalization is unwise, and, as shown in Section V, most forms are not exceptionally variable. In any case, on the above views, it is the opportunities for isolation and subsequent re-meeting which have been primarily responsible for the evolution of the *Geospizinae*, not an exceptional variability. This view is strengthened by the existence of *Pinaroloxias inornata*, confined to Cocos Island. There is still only one species of *Geospizinae* on Cocos, presumably because there is only one island. Had variability been the key factor, however, one would certainly have expected to find as many *Geospizinae* on Cocos as on some of the Galapagos Islands, because the degree of difference from any Galapagos forms shown by *Pinaroloxias* indicates that it has been isolated from them for a long time.

### THE CLOSELY RELATED SPECIES

The problem of the successful segregation of the closely similar species of *Geospizinae* still remains extremely difficult. Thus on most of the islands three species of *Geospiza* occur, and on Charles three species of *Camarhynchus* (two on the other islands), which so far as known show no significant differences with respect to habitat, food, feeding habits, breeding season, aggressive and sexual display, nests, or even (except for the Charles *Camarhynchus*) in plumage, while their songs overlap. The sole differences lie in size, and in the relative size of the bill. In these characters they often come extremely close to each other. Yet apart from a few

indeterminable specimens, all specimens can be identified. On some islands, the largest *Geospiza fortis* almost overlap with the smallest *magnirostris*, and are very different from the smallest *fortis*, which almost overlap with the largest *G. fuliginosa*. Again, on Charles *Camarhynchus psittacula* and *C. pauper* have a wide overlapping in all measurements except in depth of bill (there are also slight plumage differences). Hence among these species one sometimes finds two specimens extremely similar in all external characters, but still of different origin and genetic constitution. How such species keep distinct is extremely difficult to understand. That they normally do keep distinct, however, is shown by the frequency distributions for mensural characters of wing and bill, which lie on approximately normal curves for each species, while intermediate specimens are rare. Hybridization between species, if it occurs at all on the larger islands, certainly is rare, so presumably there is a marked degree of intersterility between these closely related species, despite their similar appearance.

#### ORIGIN OF THE LARGER UNITS

Closely related species of Geospizinae are presumed to differ primarily in characters which are nonadaptive, except in so far as they function for species recognition, and have evolved from geographical forms whose differences are primarily nonadaptive. Such specific differences have doubtless been intensified by selection in instances where they serve for recognition. Once specific segregation, however, has been established and the two forms no longer interbreed, divergent evolution is possible, and adaptive differences often appear. *Geospiza scandens* illustrates an intermediate stage in this process, since its bill is undoubtedly adapted for feeding both on *Opuntia* flowers and on ants. Since *Opuntia* flowers are seasonal, during part of the year *scandens* feeds like other forms of *Geospiza*. The larger units, represented by the genera among the Geospizinae, clearly differ in adaptive, as well as nonadaptive, characters, as shown by the correlations between bill and feeding habits, discussed in Section III. (See especially *Cactospiza* and *Certhidea*.) Presumably such adaptive radiation has been greatly assisted by the absence of food competitors and of predators, as discussed earlier. These last two factors presumably account for the fact that, as stated by Sushkin (1929, p. 377), "In the insular

faunae the amount of adaptive radiation within narrow systematical limits proves to be much larger than on the continents."

#### AN EVOLUTIONARY TREE OF THE GEOSPIZINAE

It is interesting to attempt to reconstruct evolutionary trees. In the Geospizinae there are probably many extinct intervening forms, hence all reference to relationships are tentative. Both Sushkin (1925) and Lowe (1936) consider the Geospizinae most closely related on anatomical grounds to the West Indian genus *Euetheia* (also called *Tiaris*). I find that *Euetheia* also resembles the Geospizinae in that it shows black or partially black plumage in the male, a seasonal darkening of the bill and long, dense, fluffy rump feathers, while Dr. Wetmore writes me that it builds a partial roof over the nest-cup. Separately, such characters are not of great significance, since all occur in other tropical passerine birds; together, they are at least suggestive of relationship.

If *Euetheia* is closest to the ancestor of the Geospizinae, then, of the Geospizinae, *Geospiza fuliginosa* is probably closest to the primitive geospizine stock, for small *G. fuliginosa* closely resembles species of *Euetheia* in appearance. In addition, *G. fuliginosa* shows the following primitive or generalized geospizine features: (1) the adult male has black plumage (the evidence that this is the primitive condition in Geospizinae is discussed in Section IV); (2) it has the most generalized and varied feeding habits of any form, and eats all the types of food eaten by any of the Geospizinae, save that it does not excavate in wood or catch insects on the wing, which are clearly specialized habits; (3) it has the most generalized type of song of any species; (4) it breeds in the coastal and intermediate zones, which are the most primitive habitats; (5) its bill is the most generalized of any, considering the fringillid ancestry; (6) it is widely distributed in the islands.

*Geospiza fortis* and, with it, *magnirostris* are closely related to *fuliginosa*. *Geospiza scandens* probably represents another line from *fuliginosa*, with the latter's split tongue and habit of feeding on *Opuntia* flowers more developed. *Geospiza conirostris* probably developed from *scandens*, but the reverse is also possible, and there may have been hybridization (see discussion in Section V). The evolution of *G. d. difficilis* and *debilirostris* from *fuliginosa* has already been indicated. *Geospiza d. septentrionalis* of Culpepper and Wenman islands probably fits in here, as, in addition to close

similarity in bill, it resembles *debilirostris* both in the dark female plumage and the bright rufous wing bar and undertail coverts. However, I am not completely convinced of this relationship. *Pinaroloxias inornata* possibly came from near *G. d. septentrionalis* as it shows many similarities in plumage; if this is so its resemblance to *Certhidea* in bill is due to convergence.

Of the other genera, *Certhidea* is certainly the most distinct from *fuliginosa*; this applies especially to bill, plumage, feeding habits, and song. This suggests that it was the first to separate off from the main stock. That it is an old form is also indicated by its wide distribution (it is the only species found on every island), and by the degree to which it has differentiated into island races. However, it has not given rise to more than one species. An alternative suggestion for *Pinaroloxias* is that it became separated from a *Certhidea*-like form after the latter had acquired feeding habits of the warbler pattern, with some correlated bill adaptation, but before it started to lose the black plumage in the male. The rufous wing bar, which suggests affinities with *G. d. septentrionalis*, is also found in some island forms of *Certhidea*.

In the three remaining genera, the closest to the *Geospiza fuliginosa* stock is *Camarhynchus*; bill, feeding habits, and song all suggest this. In these respects *C. parvulus* seems more primitive than *C. psittacula*. The relationship of *C. pauper* to *C. psittacula* has been discussed. *Cactospiza* was probably derived from a common ancestor with *Camarhynchus*; its song is more like that of *Camarhynchus* than that of any other Geospizinae; it carries further the tendency for loss of black male plumage, and it has similar feeding habits, in that it picks insects off the vegetation and excavates for them in wood, but the latter habit is more specialized in *Cactospiza* where there is an associated stick-probing habit, and the bill is adapted for excavating. *Cactospiza heliobates* seems more primitive than *C. pallida* in its shorter beak and more streaked plumage, but is of very restricted distribution. I have no views on the relationship of these two species.

The remaining genus, *Platyspiza*, also seems closer to *Camarhynchus* than to any other genus, agreeing with it in the partial suppression of black male plumage, the habit of frequenting the trees rather than, like *Geospiza*, the ground, and, to some extent, in the shape of its bill. It has, however, quite different feeding habits, and a specialized song, so probably diverged at an early stage, and



certainly before *Cactospiza* became differentiated from *Camarhynchus*. *Platyspiza* is the only sharply separated geospizid form sufficiently distinct to warrant generic rank which has not evolved either into several species or into island races. The reason for this is unknown.

#### COMPARISON WITH OTHER INSULAR SPECIES

In most insular birds, there is only one form on each island, a principle illustrated by *Nesomimus* on the Galapagos. However, exceptions to this are not infrequent. Stresemann (1927-34) cites the two chaffinch species, *Fringilla teydea* and *F. coelebs canariensis*, of the Canary Islands, also three *Zosterops* species, *Z. albugularis*, *Z. tenuirostris*, and *Z. lateralis norfolkensis*, on Norfolk Island. These instances are due to two, and in the second case three, successive dispersals of the same mainland form to the islands. Similarly, Mayr (1933*d*, p. 323) found two species of *Ptilinopus* in the Marquesas, two *Aplonis* on Ponape, two *Halcyon* on Palau and Samoa, and, in a recent summary, Mayr (1940, p. 271) gives a number of other examples also due to two waves of colonization of the same species from outside. Hence they are not strictly comparable with the situation on the Galapagos, where the different forms are presumed to have originated within the archipelago. However, a few cases, and two in particular, do seem comparable to the Geospizinae. Lowe (1923, pp. 519-523) finds two species of finch, *Nesospiza wilkinsi* and *N. acunhae*, on the same islands in the Tristan da Cunha group. There are only three islands, so this example is a Galapagos in miniature, and, interestingly enough, the two species differ primarily in size of bill, and also show a tendency to lose the full male plumage. At the other extreme are the famous Drepanididae of Hawaii (cf. Perkins, 1903, pp. 368-440), which, in the degree of their differentiation and specialization, have proceeded considerably further than the Geospizinae. The principles involved, however, seem the same, and, like the Geospizinae, they have spread into many ecological niches not normally occupied by Fringillidae; Sushkin (1929) considers that the Drepanididae are a branch of the Fringillidae. I regard the Geospizinae as being at a stage intermediate between the condition of the Tristan da Cunha *Nesospiza* and of the Hawaiian Drepanididae. In only a few other instances, two closely related species of endemic land birds occur on the same island. Thus Perkins (1903) finds that

*Phaeornis*, a genus of Turdidae in Hawaii, is represented by one form on each main island, except on Kauai where two occur. Similarly, Mayr (1933a, pp. 18-20) finds two species of *Mayrornis* on Ongea Levu, both of which are thought to have originated within the Fiji group.

On oceanic islands other groups of land animals sometimes show a type of evolution similar to that of the Geospizinae. In the insects of oceanic islands, Buxton (1938) notes the high proportion of endemics, the development of remarkable and peculiar types, and the extreme variability of certain species. Moreover, and here the parallel with the Geospizinae comes especially close, the members of a genus sometimes form a "complex" of species, with much individual variation, so that it is sometimes hard to arrive at specific determinations. He particularly cites the coleopteran genus *Proterhinus*, represented in Hawaii by 130 species when Perkins wrote in 1903.

The condition found among the Geospizinae is rare among birds. Since groups of small islands are common in many parts of the world, it remains to inquire why the Galapagos, Hawaii, and, to a less extent, Tristan da Cunha, should be so exceptional. The most important factors would seem to be: first, conditions of extreme isolation of the archipelago so far as the birds are concerned; second, the respective birds must have arrived on the respective islands a very long time ago but yet without the arrival of other species forming food competitors or predators (this would presumably happen where colonization was very difficult). A third condition, suggested by the absence of any such phenomenon on single islands which have been extremely isolated for a very long time, is that for such evolution to occur there must be several islands a moderate distance apart. Indeed, that this type of evolution has occurred only where there are several islands in the group is additional strong evidence for Rensch's view that the primary requirement for species formation in birds is geographical isolation with possibilities for re-meeting later.

## SUMMARY

The expedition to the Galapagos Islands from mid-December, 1938, to early April, 1939, had three main fields of inquiry with regard to the endemic finches of the archipelago: (1) breeding behavior, (2) ecology, (3) hybridization. The first two were covered adequately, but the breeding experiments were not successful. Thirty captive birds survived the trip from the Galapagos to San Francisco, California, and these were placed in aviaries at the California Academy of Sciences. The taxonomy of the group is extremely complicated, but Swarth (1931) did much to clarify most of the pre-existing confusion.

The following modifications of Swarth's systematic treatment of the *Geospizinae* are suggested. The birds from Culpepper Island placed under *Geospiza magnirostris* are moved to *Geospiza conirostris darwini* Rothschild and Hartert. The type of *Geospiza harterti* Ridgway was correctly synonymized by Swarth with *G. fuliginosa*, but many specimens from Daphne and Crossman islands, originally referred to the same form, are not *fuliginosa*, nor, as considered by Swarth, are the Daphne birds *fortis*. They may be hybrid *G. fortis* × *G. fuliginosa* populations. *Geospiza acutirostris* Ridgway cannot be separated from *G. difficilis* Sharpe, even subspecifically, so the former becomes a synonym of the latter. *Geospiza septentrionalis nigrescens* Swarth cannot be separated from *G. s. septentrionalis* Rothschild and Hartert, and *septentrionalis* is considered a subspecies of *G. difficilis*. Two specimens from Narborough Island are possibly referable to an undescribed form of *difficilis*. *Geospiza nebulosa* Gould is not a synonym of *G. fortis*, but a form, now apparently extinct, related to *G. difficilis*. The four races of *Geospiza scandens* (Gould) are merged, although the form on Bindloe Island is separable from that on James. *Cactospiza pallida producta* (Ridgway) is merged with *C. p. pallida* (Sclater and Salvin). The species of *Certhidea* are considered as subspecies of *Certhidea olivacea* Gould.

The following-named forms are not considered valid species, but merely variants, or possibly hybrids, not safely assignable to any known species: *Cactornis brevirostris* Ridgway, *Camarhynchus aureus* Swarth, *Camarhynchus conjunctus* Swarth, and *Cactospiza giffordi* Swarth. A few specimens seem intermediate between *Geo-*

*spiza magnirostris* and *G. fortis*, between *G. fortis* and *G. fuliginosa*, between *Camarhynchus psittacula* superspecies and *C. parvulus*, and possibly between *G. fuliginosa* and *G. difficilis*, and cannot safely be assigned to either of the species concerned.

Pair-formation in the Geospizinae follows the typical pattern in territorial songbirds. Postures are extremely generalized, similar in all species, and similar for aggression, sexual behavior, and food-begging by the young. Nest-building and nest-visiting are prominent in the sexual display, and one species frequently utilizes the nest of another. Courtship also includes sexual flights and male feeding female. Only the female incubates, the male feeding her near the nest. Both sexes feed the young in the nest, but only the male feeds the fledglings. The songs are generalized, and the songs of the different species overlap.

In aggressive behavior many of the species appear to recognize each other primarily by bill differences. Experiments on *Geospiza fuliginosa* with mounted birds demonstrated some sexual discrimination by plumage and some specific differentiation by bill, but neither was absolute. Breeding habits have been far more conservative than food habits in the evolution of the Geospizinae.

Provided *Cactospiza* is grouped with *Camarhynchus*, the main genera of Geospizinae have different feeding habits. The species within the genera feed largely on similar foods, *Geospiza scandens* being a partial exception. The bill is adapted to specialized feeding habits in *Certhidea*, *Cactospiza*, and *Geospiza scandens*, but many bill differences, especially those between closely related species, cannot be correlated with food differences. *Cactospiza pallida* uses spines and twigs for probing insects from crannies. This is one of the few known instances of use of tools by animals other than man.

The nests of all species are similar, and are located in similar sites, excepting that only the species of *Geospiza* utilize the plant *Opuntia*.

Habitat differences separate closely related species in two instances. Most closely related species frequent extremely similar habitats, and *Geospiza magnirostris* and *G. fortis* occupy identical ecological niches. In all species most of the breeding occurs during the rainy season. *Geospiza scandens* and *Cactospiza pallida* start nesting before the others.

Censuses could not be taken. Estimates are given, varying from about 20 adults per acre in rich, intermediate forest to about two

per acre (or less) in the open country on the tops of the larger islands. Some well-defined species are represented by total populations of only a few thousand individuals.

Adult males of *Geospiza* are black, but they frequently breed in immature plumage. The fully adult plumage in species of *Platyspiza* and *Camarhynchus* corresponds to a transitional stage in *Geospiza*, and in *Cactospiza* the black has been lost entirely, except for one individual examined which was black-headed. In *Platyspiza* and *Camarhynchus*, the disappearance of black male plumage appears to be occurring at different rates on different islands. Loss of male secondary sexual plumage characters is not uncommon in insular forms; perhaps this is correlated with the disappearance of its function in specific recognition by the female.

Differences in the female plumage of the species and island forms mainly concern the shades of brown, gray, or olive of the upper parts, the degree of streaking of the under parts, and the color of the wing bars. The differences between the island forms and species do not seem to be adaptive in character.

In the Geospizinae, plumage characters have been much more conservative in evolution than the size and shape of the bill. In *Certhidea*, the northernmost form closely resembles the southernmost, and the next most northerly one resembles another southern form, while those on the central islands are more like each other. In the breeding season, bills of adult Geospizinae are dark; outside of the breeding season they are yellowish. Older males have longer wings than younger males, which in turn have longer wings than females. Males have larger bills than females, except in *Certhidea*, in which the female has a longer bill than the male.

The island populations of each species are often slightly differentiated by mensural characters, although often not sufficient to justify subspecific recognition. Each island population seems to have evolved independently, with periodic disturbances through inter-island wandering, which appears to be uncommon. *Geospiza conirostris conirostris* is slightly differentiated on two islands less than a mile apart. Small isolated populations of *Geospiza magnirostris* and *G. fortis* have a lower variability in measured characters than large populations. The other species do not show this phenomenon.

Correlation of bill and wing, and of culmen with depth of bill, is high in most species, especially the larger ones; although it may

be absent in a few species. *Geospiza magnirostris*, *fortis*, and *fuliginosa* seem structurally to differ from each other solely in general size and in relative size of bill. The specific limits sometimes occur at different values on different islands. On some islands, *G. fortis* is so variable that larger individuals are closer to *magnirostris* and smaller ones to *fuliginosa* than they are to each other. The ratio of wing to culmen and the ratio of culmen to depth of bill show no allometric relation within each species, but have a typical average, with wide individual variation, for each species. A few intermediate specimens cannot safely be assigned. The forms on Daphne and Crossman are thought to be of hybrid origin between *fortis* and *fuliginosa*. The forms of *Camarhynchus* also differ primarily in size and in relative size of bill, a phenomenon which is rare in closely related species of birds. Most species of Geospizinae are not abnormally variable, but a few are. *Geospiza conirostris darwini* of Culpepper is thought to be of hybrid origin.

Birds have not reached the Galapagos Islands via a land bridge, although the islands were probably connected with each other at some period in the past. The few land birds which have reached the Galapagos show very different degrees of differentiation from their mainland ancestors, probably correlated with differences in times of arrival. The small isolated islands have fewer resident species of the Geospizinae, and a higher proportion of endemic forms than have either the larger or the central islands.

The most important factors in the evolution of the Geospizinae have probably been the almost complete absence of food competitors and predators, and the existence of several islands which provided partial, but not complete, isolation for island forms. Differences between island forms of the same species are considered nonadaptive, and due primarily to the "Sewall Wright effect," while colonization by an atypical sample may be a subsidiary factor.

Species probably originated mainly through geographically isolated races which later met and kept distinct, but some forms may be of hybrid origin. Differences between closely related species are nonadaptive except that bill characters serve in species recognition. The main genera show an adaptive radiation. The species of Geospizinae are not as sharply defined as in mainland birds, but they do not show the degree of overlapping or of hybridization sometimes claimed for them, and there is no need to assume for them some quite exceptional method of evolution.

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# MAIN TABLES

Main Tables—I  
Average and Extreme Measurements and Standard Deviation in *Geoplin magnirostris*

Islands	Length of culmen			Depth of bill			Wing length		
	No.	Males Measurements	σ	No.	Males Measurements	σ	No.	Males (Black) Measurements	Females Measurements σ
Neuma	10	15.65 (14.8-17.0)	.636	4	15.80 (15.1-16.4)	.572	9	86.2 (84-88)	4 82.0 (80-83) 1.29
Tower	29	16.52 (15.3-17.7)	.599	17	16.32 (15.2-17.3)	.592	24	21.21 (18.6-23.2)	1.127 11 20.87 (19.6-21.7) .615
Abington	50	16.04 (14.8-17.3)	.657	29	15.60 (14.1-16.6)	.653	47	20.01 (18.2-22.1)	.941 25 18.92 (17.4-20.5) .783
Bindloe	41	15.19 (13.8-17.4)	.770	11	15.00 (13.4-16.0)	.704	40	19.10 (17.1-21.1)	.954 10 18.70 (15.4-19.9) .973
James	46	15.91 (13.8-17.4)	.702	21	15.70 (13.0-17.1)	1.003	43	20.50 (17.1-22.1)	1.025 16 19.39 (16.1-21.0) 1.305
Jarvis	35	15.29 (13.9-17.0)	.720	13	14.95 (14.1-16.1)	.659	33	18.56 (15.8-20.5)	1.067 13 17.93 (16.9-19.3) .775
Seymour	1	13.30		3	14.73 (14.0-15.3)	.666	1	17.30	3 17.37 (15.3-19.2)
Indefatigable	13	15.28 (14.0-16.3)	.799	13	14.88 (13.9-16.4)	.735	14	19.11 (16.3-21.0)	1.753 13 18.62 (15.7-21.2) 1.633
Duane	1	14.80		3	15.13 (14.4-15.7)	.666	1	18.80	1 19.20
Marborough	1	15.70		2	14.20 (13.9-14.5)				
M. Albatross	3	15.17 (14.4-16.0)	.802	1	13.30		1	19.00	2 17.25 (16.7-17.8)
S. Albatross	8	15.27 (13.9-16.6)	.991	1	14.90		1	18.50	1 18.30
Harrington	2	15.20 (15.2-15.2)					7	18.41 (16.3-20.5)	1.862 2 18.55 (17.2-19.9)
Charles	1	14.90					2	18.10 (16.8-19.4)	
Charles	1	14.90					1	18.80	
Barvin's									
"Magnirostris"	3	18.43 (18.0-18.9)	.451	4	17.73 (17.4-18.3)	.403	3	23.67 (23.6-23.7)	.058 3 23.10 (22.7-23.7) .529
Barvin's									
"Strenua"	4	14.65 (14.1-15.8)	.785				2	15.55 (15.5-15.6)	

\* Partly Black Male

Main Tables—II  
Average and Extreme Measurements and Standard Deviation in *Geospiza fortis*

Islands	No.	Males			Females			Depth of bill			Males			Females			Wing length		
		Measurements	$\sigma$	No.	Measurements	$\sigma$	No.	Measurements	$\sigma$	No.	Measurements	$\sigma$	No.	Measurements	$\sigma$	No.	Measurements	$\sigma$	No.
Wenman	1	13.20						1	14.00					1	72.0*				
Tower	1	11.30						1	12.10										
Abingdon	48	11.25 (10.3-12.5)	.511	23	11.05 (10.1-11.8)	.353	42	11.82 (10.6-14.1)	.661	19	11.51 (10.5-12.9)	.541	11	66.6 (64-72)	2.06	22	62.4 (58-66)	2.15	
Bindloe	36	11.66 (10.6-12.5)	.466	17	11.39 (10.9-11.9)	.315	35	12.11 (11.4-12.9)	.410	15	12.15 (11.1-12.8)	.473	14	66.9 (65-70)	1.27	17	64.0 (61-67)	1.57	
Jamez	46	11.49 (10.0-12.6)	.556	23	11.40 (10.3-12.4)	.599	43	12.50 (10.5-13.9)	.714	23	12.00 (10.6-13.9)	.781	24	71.5 (69-77)	1.75	24	68.7 (65-75)	2.14	
Jervis	10	11.52 (11.1-12.2)	.377	6	11.18 (10.2-11.7)	.512	8	12.56 (12.0-13.5)	.568	6	12.18 (11.3-13.9)	.924	4	71.5 (71-72)	0.57	6	68.5 (67-71)	1.52	
Seymour	26	11.69 (9.8-13.4)	.780	31	11.49 (10.4-13.5)	.662	24	12.55 (10.7-14.3)	.957	24	11.96 (10.8-14.8)	.919	12	71.2 (69-73)	1.70	31	69.4 (63-75)	2.53	
Indefatigable	105	11.95 (10.5-13.9)	.809	49	11.83 (10.6-13.7)	.680	100	12.82 (10.7-16.6)	1.321	48	12.43 (10.9-15.3)	1.183	31	72.6 (69-79)	2.79	49	69.0 (63-77)	3.61	
Duncan	30	11.26 (10.1-13.6)	.728	20	11.18 (10.2-12.5)	.554	25	11.46 (10.0-14.8)	.862	19	11.52 (10.5-13.9)	.946	10	69.7 (65-73)	2.26	20	67.5 (64-72)	2.59	
Harborough	15	11.55 (11.0-12.3)	.481	3	11.37 (10.9-12.1)	.643	15	12.30 (11.3-13.6)	.516	2	12.30 (11.6-13.0)		15	70.5 (67-74)	1.85	3	68.7 (67-70)	1.53	
N. Albemarle	65	11.49 (10.1-13.3)	.726	34	11.53 (9.9-13.5)	.880	64	12.41 (10.3-15.6)	1.055	34	12.24 (10.2-15.2)	1.209	30	71.0 (66-75)	2.14	40	68.6 (64-74)	2.22	
C. Albemarle	9	11.40 (10.2-12.5)	.934	2	11.85 (11.8-11.9)		7	12.97 (10.5-15.0)	1.692	2	11.50 (11.0-12.0)		7	70.7 (67-74)	2.93	2	68.5 (64-73)		
S. Albemarle	70	12.45 (10.0-14.0)	.831	56	12.03 (9.8-14.0)	.987	65	13.86 (10.9-15.8)	1.169	50	13.08 (10.4-15.8)	1.424	27	75.3 (72-80)	2.26	57	71.0 (61-79)	3.32	
Barrington	6	11.78 (11.4-12.2)	.293	3	11.33 (11.0-11.8)	.416	6	12.75 (12.0-13.8)	.632	3	11.57 (10.3-12.9)		4	71.8 (71-72)	0.50	3	67.0 (62-71)	4.36	
Chatham	109	12.20 (9.9-13.7)	.668	64	12.04 (10.3-13.8)	.765	101	13.21 (10.8-16.0)	1.131	57	12.88 (10.5-16.4)	1.296	56	73.7 (69-78)	2.08	64	69.6 (65-78)	2.59	
Hood	8	11.70 (11.0-12.7)	.659	7	11.67 (10.9-13.2)	.864	8	12.46 (11.3-13.8)	.837	7	12.09 (11.4-13.4)	.784				7	68.6 (66-71)	1.72	
Charles	181	11.65 (9.8-14.2)	.883	93	11.29 (10.0-13.8)	.818	173	12.50 (10.1-16.6)	1.222	81	11.79 (10.2-14.8)	.963	102	72.1 (67-80)	2.47	97	68.8 (65-78)	2.30	
? <i>Geospiza fortis</i> $\pm$ <i>G. fuliginosa</i>																			
Daphne	31	10.51 (9.2-11.3)	.542	11	10.33 (9.2-11.8)	.817	26	10.67 (8.6-11.9)	.728	11	10.35 (9.1-11.8)	.819	23	67.4 (65-70)	1.62	11	65.0 (63-68)	1.73	
Crossman	12	9.32 (8.0-11.2)	.873	4	9.08 (8.1-10.3)	.911	11	9.55 (8.3-10.4)	.802	3	9.40 (8.5-10.2)	.854	8	65.6 (63-67)	1.51	2	64.5 (64-65)		

\* Juvenal male

Main Tables—III  
Average and Extreme Measurements and Standard Deviation in *Geopis fuliginosa*

Islands	Length of culmen			Depth of bill			Wing length		
	No.	Males Measurements $\sigma$	Females Measurements $\sigma$	No.	Males Measurements $\sigma$	Females Measurements $\sigma$	No.	Males (Black) Measurements $\sigma$	Females Measurements $\sigma$
Woman	1	8.70	3 8.33 (7.9-8.9)	3	7.97 (7.8-8.3)	1* 60.0*	3	59.3 (58-60)	1.15
Abingdon	48	8.22 (7.5-9.1)	26 8.02 (7.3-8.7)	43	7.70 (6.7-8.5)	.441	21	58.1 (55-62)	1.70
Bindloe	24	8.08 (7.4-8.7)	21 7.86 (7.0-8.2)	19	7.40 (6.7-8.2)	.395	16	56.3 (54-59)	1.43
Jamez	23	8.43 (7.4-9.1)	12 8.45 (7.9-9.3)	18	8.02 (7.4-8.3)	.209	11	63.6 (60-66)	1.46
Jervis	12	8.48 (7.9-9.3)	8 8.41 (7.8-8.9)	10	8.19 (7.5-9.0)	.425	7	64.4 (63-67)	1.67
Delphoe	2	8.65 (8.3-9.0)	1 8.20	2	8.40 (7.7-9.1)	1 7.60	1	64.0	1 62.0
Seymour	45	8.60 (7.9-9.5)	25 8.46 (8.0-9.2)	41	8.22 (7.5-9.0)	.359	17	7.72 (6.9-8.4)	.387
Indefatigable	80	8.42 (7.5-9.3)	43 8.44 (7.4-9.4)	76	8.17 (7.5-9.3)	.380	37	7.84 (7.2-8.9)	.420
Duncan	84	8.59 (7.7-9.6)	30 8.53 (7.1-9.4)	73	8.13 (7.3-9.0)	.337	24	8.04 (7.4-8.4)	.283
Marborough	19	8.07 (7.6-8.5)	11 8.04 (7.5-8.9)	15	7.91 (7.4-8.4)	.292	7	7.71 (7.3-8.3)	.360
M. Albemarle	87	8.31 (7.8-9.2)	57 8.13 (7.0-9.4)	70	8.13 (7.5-9.0)	.285	47	7.97 (6.9-8.9)	.387
C. Albemarle	14	8.01 (7.4-8.6)	5 8.00 (7.6-8.4)	13	8.32 (7.7-9.0)	.346	6	8.05 (7.5-8.8)	.505
S. Albemarle	63	8.43 (7.9-9.6)	39 8.24 (7.5-9.1)	59	8.31 (7.6-9.5)	.422	33	7.97 (7.1-8.9)	.402
Brettle	11	8.86 (8.1-9.7)	7 8.67 (8.1-9.3)	9	8.56 (7.9-9.0)	.410	6	8.40 (7.9-9.5)	.573
Barrington	41	8.76 (8.2-9.6)	10 8.50 (8.2-8.8)	36	8.09 (6.8-8.8)	.404	7	7.94 (7.7-8.1)	.140
Chatham	125	8.79 (7.2-10.2)	108 8.64 (7.1-10.3)	112	8.08 (7.1-9.1)	.440	85	7.84 (6.9-8.7)	.438
Hood	32	8.78 (8.1-9.7)	15 8.51 (7.9-9.3)	30	8.28 (7.8-9.4)	.334	14	7.80 (7.2-8.5)	.340
Gardner (Hood)	7	8.59 (8.0-9.4)	7 8.39 (7.8-9.2)	7	8.14 (7.3-8.6)	.461	6	7.95 (7.5-8.5)	.373
Charles	86	8.59 (7.7-9.4)	87 8.41 (7.2-10.3)	71	8.14 (7.3-9.1)	.402	68	7.82 (7.2-8.7)	.318
							41	64.0 (61-70)	1.64
							87	61.2 (58-64)	1.28

\* juvenile male

Main Tables—IV  
Average and Extreme Measurements and Standard Deviation in Geophina difficilis

Islands	No.	Males		Females		Depth of bill		Females		Wing length								
		No.	Measurements	No.	Measurements	No.	Measurements	No.	Measurements	No.	Measurements							
<u>septentrionalis</u>																		
Culpepper	32	11.32 (10.5-12.2)	.426	6	11.03 (10.8-11.4)	.266	30	8.97 (8.2-9.5)	.309	4	8.58 (8.0-9.2)	.506	17	73.2 (71-77)	1.38	6	70.2 (69-72)	1.17
Wenman	67	10.67 (10.0-11.7)	.416	36	10.61 (9.8-11.3)	.362	60	8.28 (7.7-9.5)	.328	33	7.85 (7.3-8.5)	.282	26	71.9 (68-75)	1.54	35	68.5 (67-71)	1.12
<u>difficilis</u>																		
Tower	52	9.42 (8.5-10.2)	.377	28	9.18 (8.3-10.0)	.440	48	7.91 (7.2-8.5)	.328	25	7.74 (7.1-8.1)	.292	43	63.1 (60-66)	1.31	27	60.7 (58-64)	1.38
Abingdon	18	9.67 (9.0-10.2)	.305	11	9.38 (8.6-10.1)	.485	17	8.51 (7.9-9.0)	.290	10	8.42 (7.7-9.4)	.476	11	62.6 (61-64)	0.82	12	61.0 (59-63)	1.21
<u>debillirostris</u>																		
James	44	10.25 (9.5-11.4)	.387	26	10.00 (9.5-11.4)	.456	39	9.35 (8.5-10.0)	.318	25	9.11 (8.7-9.8)	.300	32	71.7 (65-76)	2.15	25	69.4 (67-72)	1.25
Indefatigable	33	9.60 (9.1-10.2)	.320	10	9.56 (9.0-10.7)	.517	29	8.67 (8.2-9.7)	.331	10	8.60 (8.1-8.9)	.279	23	69.2 (67-71)	1.27	10	67.2 (65-69)	1.32
S. Albemarle	1	10.80				1	8.20						1	71.0				
<u>Position <sup>2</sup></u>																		
Narborough	2	9.15 (9.1-9.2)				2	8.05 (8.0-8.1)						2	66.0 (66-66)				



Main Tables—V  
Averages and Extreme Measurements and Standard Deviation in Geopelia pacifica

Islands	No.	Length of culmen			Depth of bill			Wing length										
		Males Measurements	σ	No.	Females Measurements	σ	No.	Males (Black) Measurements	σ	Females Measurements	σ							
Abington	17	14.55 (13.7-15.9)	.602	12	14.43 (13.8-15.3)	.510	16	9.68 (8.9-10.7)	.459	10	9.34 (8.5-10.1)	.504	4	75.0 (72-74)	0.82	12	68.4 (64-72)	1.98
Birdsloe	9	15.07 (14.3-15.8)	.447	13	14.62 (13.6-15.8)	.623	9	10.61 (10.2-11.9)	.534	13	10.41 (9.5-11.2)	.516	5	75.2 (71-75)	1.64	13	69.7 (68-72)	1.44
James	23	12.92 (12.0-13.8)	.496	9	12.61 (11.7-13.7)	.704	21	8.84 (8.2-9.5)	.366	8	8.28 (7.8-9.0)	.403	15	69.8 (66-72)	1.40	9	66.6 (65-70)	1.67
Jervis	15	13.63 (12.4-14.5)	.633	9	13.50 (12.1-14.8)	.925	12	9.22 (8.8-9.7)	.295	9	9.11 (7.9-11.2)	.619	11	70.5 (69-73)	1.37	9	67.8 (65-70)	1.58
Daphne	1	13.90		3	14.07 (13.1-14.6)	.839	1	10.20		1	9.90		1	71.0		3	70.3 (69-71)	1.15
Seymour	40	14.74 (12.4-16.1)	.717	24	14.83 (13.6-16.3)	.616	34	9.74 (9.0-10.6)	.411	21	9.44 (8.9-9.9)	.311	21	72.1 (69-76)	1.66	24	69.3 (65-72)	1.80
Indefatigable	87	14.95 (13.0-16.4)	.767	33	15.01 (12.9-16.8)	.819	80	9.75 (8.5-10.7)	.433	33	9.49 (8.3-10.7)	.556	40	72.6 (70-75)	1.11	32	69.3 (66-72)	1.18
Duncan	8	14.64 (14.0-15.1)	.487	10	14.31 (13.1-15.0)	.590	7	9.74 (9.1-10.0)	.355	7	9.29 (8.4-10.2)	.607	1	71.0		10	70.3 (67-74)	2.11
Cowley	2	13.55 (13.4-13.7)					2	8.60 (8.2-9.0)					1	72.0				
S. Albemarle	16	14.64 (13.7-16.0)	.705	5	14.08 (12.7-15.1)	1.143	16	9.59 (8.9-10.0)	.365	5	9.00 (8.8-9.4)	.255	5	74.2 (73-75)	1.10	5	69.4 (66-74)	3.44
Barrington	61	14.40 (12.8-16.4)	.704	22	14.20 (12.8-15.6)	.768	50	10.11 (9.3-11.4)	.482	22	9.89 (9.0-10.5)	.384	37	71.4 (68-75)	1.30	22	68.8 (66-73)	1.74
Chatham	7	13.30 (11.7-14.0)	.906	8	12.48 (11.8-14.1)	.440	7	9.73 (9.3-10.2)	.368	5	9.28 (9.1-9.5)	.164				8	66.9 (65-69)	1.81
Charles	102	13.88 (12.6-15.2)	.618	33	13.61 (12.3-15.0)	.649	90	9.43 (8.4-10.4)	.392	29	8.90 (8.2-9.8)	.340	59	71.2 (68-75)	1.54	33	68.2 (65-71)	1.63

Main Tables—VI  
Average and Extreme Measurements and Standard Deviation in *Geospiza crassirostris*

Islands	Length of culmen			Depth of bill			Wing length											
	No.	Males Measurements $\sigma$	Females Measurements $\sigma$	No.	Males Measurements $\sigma$	Females Measurements $\sigma$	No.	Males (Black) Measurements $\sigma$	Females Measurements $\sigma$									
Culpepper	17	14.99 (13.6-16.2)	.874	6	14.96 (13.8-17.0)	1.078	16	16.53 (12.3-19.1)	2.171	6	16.03 (12.3-18.5)	2.263	17* 82.3* (77-87)	2.85	7	77.9 (72-80)	2.67	
Tower	43	14.35 (13.0-16.4)	.762	25	14.16 (13.4-14.7)	.383	40	12.98 (11.1-15.3)	.958	19	12.63 (10.5-15.8)	1.195	30	77.4 (74-81)	1.98	24	73.3 (69-76)	1.83
Hood	87	15.43 (13.0-17.4)	.938	52	14.83 (13.5-16.7)	.863	80	15.97 (13.3-18.7)	1.104	51	15.05 (13.3-17.0)	.912	64	79.8 (74-84)	2.37	43	76.1 (73-79)	1.83
Gardner (Hood)	72	14.64 (12.3-17.0)	.987	45	14.06 (12.2-16.2)	.970	67	15.05 (12.6-17.0)	1.113	40	14.30 (12.1-16.8)	1.194	38	78.9 (69-84)	2.43	42	75.2 (71-80)	2.30
Gardner (Charles)				1	13.50					1	14.30					1	76.0	

\* On Culpepper, the partly black were added to the black males, as, with so variable a form, the figures for the five available black males may be misleading. (For these five, No.-5; Mean-81.8;  $\sigma$  4.44; range as above.)

Average and Extreme Measurements and Standard Deviation in *Platyziza crassirostris*

Islands	No.	Males		Length of culmen		Depth of bill		Males (Partly Black)		Wing length								
		Measurements	$\sigma$	No.	$\sigma$	No.	$\sigma$	No.	$\sigma$	No.	$\sigma$							
Abington	16	10.43 (9.8-11.0)	.398	10	10.23 (9.7-10.9)	.327	13	12.23 (11.3-13.0)	.477	10	11.91 (11.5-12.6)	.311	8	84.9 (84-87)	0.94	7	79.7 (79-83)	1.50
Bindloe	5	10.60 (10.1-11.1)	.361	14	10.27 (9.5-11.3)	.414	5	12.96 (12.5-13.5)	.365	8	12.23 (11.7-12.7)	.328	4	85.5 (85-87)	1.00	13	81.3 (79-85)	1.49
James	26	10.55 (9.6-11.1)	.342	12	10.13 (9.8-10.3)	.182	13	12.79 (12.1-13.6)	.491	7	12.09 (11.9-12.7)	.291	20	87.3 (85-91)	1.74	12	85.2 (81-86)	1.59
Jervis	3	10.30 (10.2-10.4)	.141				2	12.80 (12.6-13.0)										
Indefatigable	28	10.43 (9.9-11.0)	.282	27	10.14 (9.5-10.7)	.283	23	12.31 (11.5-13.1)	.338	18	12.15 (11.0-13.3)	.495	16	86.1 (84-89)	1.20	26	82.6 (79-86)	1.53
Duncan	7	10.37 (10.0-10.6)	.265	3	10.03 (9.8-10.5)	.404	2	12.60 (12.6-12.6)		3	12.00 (11.4-12.6)	.600				3	79.3 (78-81)	1.53
Narborough	5	9.74 (9.5-9.9)	.182	3	9.73 (9.3-9.9)	.287	5	12.24 (11.8-13.1)	.513	3	11.67 (11.3-12.2)	.473	5	80.0 (78-83)	2.00	4	77.5 (77-79)	1.00
N. Albemarle	10	10.05 (9.6-10.9)	.497	4	9.85 (9.6-10.3)	.283	8	11.95 (11.3-12.4)	.424	4	11.75 (11.1-12.3)	.500	6	82.5 (80-84)	1.38	4	78.8 (78-80)	0.96
S. Albemarle	56	10.26 (9.6-10.9)	.284	25	10.02 (9.5-10.6)	.313	42	12.00 (10.6-12.9)	.534	18	11.57 (10.9-12.6)	.456	34	84.2 (79-88)	1.87	26	80.8 (75-84)	2.04
Chatham	37	10.47 (9.9-11.3)	.319	15	10.18 (9.3-10.8)	.430	30	12.64 (11.7-13.5)	.444	12	12.43 (11.7-13.0)	.339	9	85.2 (83-88)	1.48	15	82.3 (77-88)	2.61
Charles	24	10.69 (10.0-11.3)	.353	29	10.44 (10.0-11.4)	.356	15	12.60 (11.6-13.3)	.477	15	12.15 (11.2-13.1)	.536	5	86.4 (85-88)	1.34	28	82.7 (80-86)	1.47

Main Tables—VII  
Average and Extreme Measurements and Standard Deviation in Camrynchus psittacula Superspecies

Island	Length of culmen			Depth of bill			Males (Partly Black)			Wing length		
	No.	Measurements	σ	No.	Measurements	σ	No.	Measurements	σ	No.	Measurements	σ
<u>C. habeli</u>												
Abiton	18	10.13 (9.4-10.7)	.322	27	9.96 (9.4-11.0)	.340	16	10.40 (9.7-11.2)	.418	22	10.05 (9.4-11.2)	.446
Blindoe	24	10.49 (9.9-11.3)	.378	15	10.29 (9.8-10.7)	.250	20	10.54 (10.0-11.2)	.322	12	10.16 (9.7-10.7)	.281
<u>C. psittacula</u>												
James	17	9.84 (9.1-10.4)	.234	9	9.71 (9.0-10.2)	.389	12	11.15 (9.4-11.9)	.671	5	11.10 (10.6-11.4)	.316
Jervis	3	10.00 (9.8-10.3)	.265	2	9.60 (9.6-9.6)		1	11.70		2	10.95 (10.9-11.0)	
Indefatigable	7	9.64 (8.8-10.3)	.597	11	9.27 (8.8-9.8)	.355	7	10.69 (9.8-11.3)	.612	10	9.71 (9.0-10.9)	.582
Barrington	2	9.95 (9.8-10.1)		3	9.50 (9.0-10.4)	.781	2	11.05 (10.8-11.3)		3	11.13 (10.8-11.6)	.416
Chatham	1	10.10		1	9.60		1	12.10		1	10.80	
Charles	4	9.93 (9.6-10.2)	.250	13	9.46 (9.0-9.9)	.290	3	10.83 (10.3-11.1)	.462	10	10.34 (9.9-10.9)	.303
<u>? psittacula-affinis</u>												
Duncan	3	9.40 (9.0-10.4)	.819	6	9.37 (8.6-10.4)	.799	4	10.35 (9.8-11.2)	.619	6	10.02 (9.0-11.0)	.922
<u>C. affinis</u>												
Narborough	2	9.05 (8.9-9.2)		2	8.60 (8.2-9.0)		2	10.10 (9.9-10.3)		2	9.45 (9.0-9.9)	
N. Albemarle	4	8.90 (8.3-8.8)	.265	6	8.40 (7.9-8.7)	.276	4	9.70 (9.2-10.1)	.374	6	9.03 (8.7-9.5)	.339
C. & E. Albemarle	5	8.62 (8.1-9.2)	.466	4	8.53 (8.1-9.0)	.443	5	9.38 (9.2-9.8)	.742	2	8.75 (8.7-8.8)	
S. Albemarle	17	8.53 (8.0-9.5)	.415	16	8.36 (8.0-8.9)	.271	15	9.28 (8.5-10.3)	.477	14	9.04 (8.8-9.4)	.170
<u>C. pauper</u>												
Charles	80	9.02 (8.0-10.2)	.404	62	8.79 (8.2-9.4)	.366	66	8.83 (8.1-9.9)	.429	59	8.43 (7.5-9.3)	.370

\* stretched (No black males available)

Main Tables—VIII  
Average and Extreme Measurements and Standard Deviation in *Camarhynchus parvulus*

Islands	Males		Length of culmen		Males		Depth of bill		Females		Males (Partly Black)		Wing length		
	No.	Measurements	σ	No.	Measurements	σ	No.	Measurements	σ	No.	Measurements	σ	No.	Measurements	σ
Western															
		2	6.95 (6.9-7.0)										2	59.5 (59-60)	
	1	7.20										1*	61.0*	1	60.0
Ablington															
James	28	6.95 (6.4-7.4)	.199	16	6.91 (6.4-7.6)	.326	23	7.36 (6.5-8.0)	.346	13	7.09 (6.7-7.6)	.225	18	63.5 (60-66)	1.54
Jervis	6	7.23 (7.0-7.5)	.197	3	6.80 (6.7-6.9)	.141	5	7.66 (7.3-8.2)	.378	3	7.17 (7.1-7.2)	.058			
Indefatigable	19	7.49 (6.6-8.2)	.443	28	7.37 (6.3-8.1)	.413	12	7.32 (6.9-8.1)	.324	18	7.10 (6.7-7.6)	.279	5	64.0 (63-65)	0.63
Duncan	3	7.43 (7.1-7.7)	.306	8	7.20 (6.3-7.9)	.543	3	7.87 (7.3-8.2)	.493	7	7.51 (7.1-8.2)	.385			
Marborough	1	7.10		5	6.90 (6.5-7.4)	.367				5	7.04 (6.8-7.5)	.288	1	63.0	
N. Albemarle	14	6.97 (6.6-7.3)	.216	16	7.06 (6.6-7.8)	.286	10	7.42 (6.8-8.1)	.402	9	7.47 (7.1-8.0)	.283	6	62.5 (60-64)	1.38
S. Albemarle	24	7.28 (6.6-8.0)	.324	23	7.11 (6.5-7.7)	.275	16	7.56 (6.9-8.1)	.326	17	7.29 (6.7-8.0)	.390	16	63.4 (62-65)	1.09
Barrington	2	6.90 (6.6-7.2)		1	7.30		2	7.15 (6.8-7.5)		1	7.50				
Charles	86	7.33 (6.8-8.1)	.297	38	7.22 (6.7-7.8)	.314	54	7.51 (6.7-8.0)	.284	25	7.28 (6.8-7.8)	.307	60	64.2 (62-68)	1.52
Chatham	91	7.96 (7.0-9.3)	.310	73	7.77 (7.3-8.2)	.238	71	7.91 (7.2-8.7)	.331	62	7.60 (6.7-8.2)	.310	4	65.3 (63-67)	1.71
													75	62.4 (60-66)	1.34

\*streaked male

Main Tables—IX

Average and Extreme Measurements and Standard Deviation in Catostomus pallida

Islands	No.	Length of culmen		Depth of bill		Wing length							
		Males Measurements σ	Females Measurements σ	Males Measurements σ	Females Measurements σ	Males Measurements σ	Females Measurements σ						
James	13	12.56 (11.4-13.2)	.513	7 11.91 (11.6-12.2)	.212	9 9.29 (8.8-9.8)	.285	5 9.08 (8.8-9.5)	.268	13 75.3 (72-77)	1.49	7 71.9 (70-74)	1.57
Jervis	3	12.40 (11.6-12.9)	.572	3 12.17 (11.8-12.5)	.351	2 9.25 (9.2-9.3)		3 8.90 (8.6-9.1)	.265	3 72.3 (72-73)	0.57	3 71.0 (71-71)	
Indefatigable	9	12.11 (11.3-12.7)	.376	12 11.98 (11.5-12.6)	.327	9 9.09 (8.8-9.5)	.209	9 8.51 (8.1-9.0)	.322	8 72.8 (70-74)	1.39	12 70.2 (67-72)	1.64
Duncan	6	11.95 (11.4-12.3)	.302	2 11.90 (11.5-12.3)	.566	3 9.00 (8.8-9.2)	.200	2 9.00 (8.7-9.3)		6 72.2 (71-74)	1.17	2 68.5 (68-69)	
R. Albemarle	6	11.70 (11.2-12.0)	.283	1 11.10		6 8.78 (8.5-9.0)	.232	1 8.40		6 72.7 (70-73)	1.97	1 73.0	
Cowley	2	11.30 (11.3-11.3)		4 11.38 (11.0-11.7)	.307			3 8.07 (7.8-8.3)	.252	2 70.5 (70-71)		4 70.0 (68-72)	1.63
S. Albemarle	53	11.24 (10.4-12.2)	.432	22 10.96 (10.2-12.0)	.458	48 8.12 (7.4-9.0)	.400	24 7.81 (7.3-8.3)	.250	55 71.5 (68-77)	1.49	24 69.1 (66-72)	1.51
Chatham	8	10.80 (10.1-11.1)	.302	3 11.10 (10.9-11.5)	.316	5 8.94 (8.7-9.3)	.230	2 8.50 (8.4-8.6)		8 71.5 (69-73)	1.69	3 70.7 (69-72)	1.53
Charles	1	13.00								1 70.0			

Average and Extreme Measurements and Standard Deviation in Catostomus hellobates

Islands	No.	Length of culmen		Depth of bill		Wing length							
		Males Measurements σ	Females Measurements σ	Males Measurements σ	Females Measurements σ	Males Measurements σ	Females Measurements σ						
Albemarle and Harborough	32	10.49 (9.5-11.4)	.470	23 10.42 (9.8-11.8)	.460	29 8.15 (7.6-8.8)	.279	21 7.87 (7.2-8.9)	.420	32 71.9 (68-75)	1.60	24 70.4 (68-73)	1.32

Main Tables—X  
Average and Extreme Measurements and Standard Deviation in *Certhides olivaceus*

Islands	Length of culmen			Depth of bill			Wing length									
	No.	Males Measurements σ	No.	Females Measurements σ	No.	Males Measurements σ	No.	Females Measurements σ	No.	Males Measurements σ	No.	Females Measurements σ				
Culpepper	6	8.20 (8.0-8.4)	.129	13	8.43 (8.0-8.9)	.259	4	4.5 (4.2-4.9)	10	4.7 (4.2-5.0)	6	55.8 (54-59)	1.86	13	54.7 (51-56)	1.65
Wenman	9	7.81 (7.4-8.2)	.337	5	8.16 (7.8-9.0)	.441	9	4.1 (4.0-4.4)	4	4.2 (3.9-4.9)	10	54.8 (53-57)	1.69	5	53.0 (52-56)	1.73
Tower	41	8.18 (7.8-8.6)	.206	21	8.45 (7.6-9.0)	.354	37	4.2 (3.8-4.7)	15	4.2 (3.9-4.6)	41	54.0 (52-56)	0.95	21	53.6 (53-55)	0.75
Athington	17	8.10 (7.6-8.4)	.229	14	8.57 (8.2-9.0)	.273	12	4.0 (3.7-4.3)	8	4.1 (3.9-4.2)	18	51.5 (50-53)	0.71	14	51.1 (50-53)	1.00
Bindloe	18	8.18 (7.8-8.9)	.305	19	8.80 (8.0-9.3)	.320	12	3.9 (3.5-4.1)	13	4.1 (3.8-4.4)	18	53.8 (52-55)	0.88	19	53.3 (51-55)	1.24
James	31	7.33 (6.6-7.8)	.278	24	7.65 (7.0-8.2)	.353	21	4.1 (3.8-4.6)	17	4.2 (3.9-4.5)	31	53.6 (51-56)	1.17	23	52.9 (52-55)	0.92
Jervis	6	7.35 (7.1-7.6)	.207	3	7.80 (7.6-8.0)	.200	6	4.4 (4.1-4.9)	2	4.4 (4.2-4.5)	6	52.8 (52-54)	0.98	3	51.0 (50-52)	1.00
Indefatigable	44	7.60 (7.0-8.1)	.338	38	7.89 (7.2-8.9)	.363	32	4.3 (3.9-4.8)	35	4.4 (4.0-4.9)	43	54.1 (52-57)	1.31	39	52.9 (51-56)	1.17
Duncan	21	7.56 (7.0-8.4)	.465	8	7.67 (7.2-8.0)	.277	16	4.2 (4.0-5.5)	7	4.4 (4.1-4.9)	21	52.4 (51-57)	1.43	8	51.1 (50-56)	2.03
Narborough	10	7.34 (7.2-7.9)	.212	2	7.60 (7.3-7.9)	.10	10	4.1 (3.9-4.3)	2	4.3 (4.2-4.4)	10	53.7 (51-56)	1.49	2	52.0 (52-52)	
N. Albemarle	20	7.33 (7.0-8.0)	.288	11	7.47 (6.8-7.9)	.320	16	4.3 (4.0-4.5)	8	4.3 (4.0-4.6)	19	53.2 (51-56)	1.26	11	51.6 (51-53)	0.82
S. Albemarle	28	7.45 (6.9-8.0)	.338	6	7.70 (7.2-8.0)	.283	20	4.3 (3.9-4.6)	4	4.3 (4.2-4.5)	28	53.0 (51-55)	1.17	6	52.8 (52-54)	0.75
Groesman	8	7.97 (7.7-8.2)	.167	1	7.90		5	4.4 (4.2-4.4)	1	4.4	8	52.5 (51-54)	0.93	1	52.0	
Barrington	40	7.92 (7.1-8.4)	.300	33	8.36 (7.8-8.8)	.308	25	4.1 (3.8-4.5)	29	4.2 (3.9-4.6)	38	52.5 (50-54)	0.93	35	52.0 (50-54)	0.91
Chatham	46	7.89 (7.1-8.5)	.343	23	8.17 (7.4-9.0)	.378	39	4.2 (3.9-4.7)	17	4.4 (3.8-5.0)	46	53.5 (52-55)	0.89	25	53.1 (51-55)	1.19
Hood	44	8.02 (7.4-8.6)	.275	19	8.52 (7.8-9.0)	.373	32	4.3 (4.0-4.7)	16	4.2 (4.0-4.4)	45	52.9 (50-55)	1.07	21	52.9 (52-54)	0.70
Gardner (Hood)	43	8.00 (7.3-8.6)	.292	20	8.30 (7.8-9.1)	.345	31	4.2 (3.8-4.6)	14	4.4 (4.0-5.0)	43	53.1 (51-55)	0.98	20	52.5 (51-54)	0.83
Charles	25	7.74 (7.0-8.2)	.294	22	8.05 (7.4-8.5)	.311	19	4.5 (4.3-4.8)	18	4.8 (4.3-5.2)	25	54.9 (53-57)	0.95	23	53.8 (53-56)	0.78

Average and Extreme Measurements and Standard Deviation in *Pinaroloxias inornata*

Islands	Length of culmen			Depth of bill			Wing length											
	No.	Males Measurements σ	Females Measurements σ	No.	Males Measurements σ	Females Measurements σ	No.	Males (Black) Measurements σ	Females Measurements σ									
Cocos	124	10.41 (9.0-11.2)	.381	56	10.31 (9.5-11.0)	.303	107	6.17 (5.5-7.0)	.250	42	5.98 (5.4-6.7)	.267	78	68.1 (64-71)	1.25	43	65.4 (61-68)	1.37

PLATE 1

(Somewhat less than natural size)

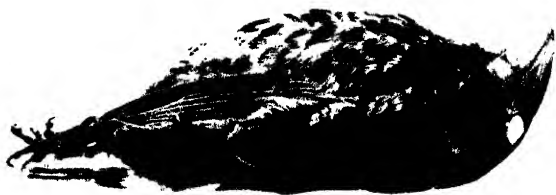
1. Large *Geospiza magnirostris*
2. Small *Geospiza magnirostris*
3. Large *Geospiza fortis*
4. Small *Geospiza fortis*



1



2



3



4



## PLATE 2

(Somewhat less than natural size)

1. Large *Geospiza fuliginosa*
2. Small *Geospiza fuliginosa*
3. *Geospiza difficilis difficilis*
4. *Geospiza difficilis debilirostris*



1



2



3



4

PLATE 3

(Somewhat less than natural size)

1. *Geospiza scandens*
2. *Geospiza conirostris*
3. Small *Geospiza conirostris*
4. *Platyspiza crassirostris*



1



2



3



4

PLATE 4

(Somewhat less than natural size)

1. *Camarhynchus psittacula*
2. *Camarhynchus pauper*
3. *Camarhynchus parvulus*
4. *Cactospiza pallida*
5. *Certhidea olivacea*
6. *Pinaroloxias inornata*



1



2



3



4



5



6



# The Coleoptera of the Galapagos Islands

BY  
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SAN FRANCISCO  
CALIFORNIA ACADEMY OF SCIENCES  
1953



OCCASIONAL PAPERS NO. XXII  
OF THE CALIFORNIA ACADEMY OF SCIENCES  
Issued July 15, 1953

COMMITTEE ON PUBLICATION

DR. ROBERT C. MILLER, *Chairman*

DR. GEORGE S. MYERS

DR. EDWARD L. KESSEL, *Editor*

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# The Coleoptera of the Galapagos Islands

## INTRODUCTION

The Galapagos Islands are on the Equator, about 600 miles from the west coast of South America. According to Alfred Russel Wallace (1880), they "stand upon a deeply submerged bank, the 1,000 fathom line encircling all the more important islands; the largest (Albemarle Island) being about eighty miles long and very irregular shaped, while the four next in importance—Chatham, Indefatigable, James and Narborough Islands—are each about twenty-five to thirty miles long and of a rounded or elongate form. The whole are entirely volcanic and in the western islands there are numerous active volcanoes." They are semiarid, the lowlands having a short wet season, while the highlands catch the fogs and rain clouds and are much moister, and have a later season. The Coleoptera are not very numerous but they are found on all the islands and some are restricted to rather definite environments as the seacoast, the semiarid lowlands, or the moister highlands. The Cicindelidae, Oedemeridae, and certain Tenebrionidae like *Phaleria* prefer the seacoast, while the Tenebrionidae dominate the barren grounds and during the rains certain Carabidae, like *Calosoma howardi* Linell, are fairly numerous and widely distributed. Later on, the highlands have their season when some Carabidae may appear in certain restricted localities. The Tenebrionidae have the greatest number of species and the three genera: *Stomion* Waterhouse, *Pedonoces* Waterhouse, and *Ammophorus* Waterhouse contain the bulk of these. The first two genera are limited to the Galapagos Islands but *Ammophorus* possesses some mainland species. The Chrysomelidae are not numerous as would be expected in such a barren region but there are a fair number of Cerambycidae and Rhyngophora. There are only a few of the Cossoninae which are so abundant on the Atlantic islands and in Polynesia but that scarcity may be due to the fact that they are, in the main, stem and twig borers and require very intensive collecting. In fact the fauna of the Islands as a whole is probably very much richer than indicated by the collections so far made. Close collecting such as was followed by Wollaston in the Atlantic islands might yield many more species, especially in certain families of small insects.

The coleopterous fauna is definitely related to that of the barren

grounds of western South America especially Ecuador and Peru, and no doubt derived from them at some period long ago. A few species like some of the Cerambycidae are the same as mainland species but these are large, fully winged species which might have arrived in rather recent times. Others, however, though superficially resembling mainland species, appear upon closer examination to be quite distinct. Most of the genera such as in the Carabidae, Elateridae, Tenebrionidae, and Rhynchophora have numerous species showing considerable reduction in the size of the true wings and as a result a modification of their form chiefly in the humeral region, resulting in more rounded shoulders and along with this the development of an elliptical afterbody. With the reduction in size of the flight organs, there is apt to occur an increase in size and a marked change in the body sculpturing. This is especially noticeable in the tenebrionid genera *Stomion* and *Pedonoeces*. This has of course been accentuated by isolation and time. The species supposedly nearest the original home are more generalized, more like the primitive stock, while those most removed are the most modified or divergent. In the characteristic genera: *Stomion*, *Pedonoeces* and *Ammophorus*, most of the species are restricted to definite islands or confined to limited areas on the islands. A few species are widely distributed though generally showing some variation in different areas, while many species are very variable, having many modifications within a given area. The fact that the Islands are volcanic and to a great extent semiarid has been a limiting factor. Only very hardy forms such as the Tenebrionidae could survive and perpetuate themselves in the drier areas. Other forms which have vulnerable larvae could only survive by adapting themselves to the seasons. This is the case with *Calosoma howardii* Linell which being fully winged is widely distributed. It is abundant at times though generally found on the lowlands in the spring when there is sufficient moisture. The higher mountains having more humid conditions, generally have a later productive season. Because of the favorable conditions, they have preserved representatives of many of the Carabidae whose vulnerable larvae could not exist in the drier areas. These areas are more limited in extent and isolated so that the species which are preserved there are apt to show marked divergences and limitations as to populations. This isolation has also enabled many species to become more or less flightless because of degenerative changes in the wings. This has of course increased the isolation of the species. The prominent genus *Calosoma* which will be discussed in detail later on shows these wing modifications to a notable degree.

The fauna of the Galapagos Islands, because of its long isolation,

has acquired certain peculiar features which throw light upon many of the problems of nature. The fauna is limited in extent and most of its species and certain of its genera are confined to the Archipelago. A great deal of divergence is shown in the species, particularly in the larger genera, and most species are restricted to certain islands or even to special areas on the islands. This is not a haphazard distribution either. There is a relationship between the variations of the species and their distribution. This seems to indicate that the modifications which have taken place have been made possible by the gradual isolation of the different species such as could be produced by the breaking up of larger islands into smaller ones, modifications in topography, and climatic changes. This subject will be discussed in more detail later on when certain of the larger or more peculiar genera are examined. The fauna as a whole is related to that of the western portion of South America. There seems to be no extraneous element. It would appear as if a certain portion of western South America was isolated by the subsidence of the intervening area between the Islands and the mainland. This land mass was later broken up into small islands, probably by subsidence subject to extensive volcanic action and desiccation. These factors in time reduced the fauna and accelerated the various divergent modifications. Because of the extensive volcanic action on the Islands and the deep ocean bed between them and the mainland, they have been listed as oceanic islands by Alfred Russel Wallace and others. I do not believe this. I believe that the Islands are continental and that an extensive subsidence of the coastal area of western South America coincided with the elevation of the northern Andes which the geologists believe has occurred in later geological times, has accounted for their isolation.

The first Coleoptera collected in the Galapagos Islands were obtained in 1835, by Charles Darwin, while on the historical *Beagle* Expedition. The collection was small, consisting of twenty-nine species, but it was significant in that the species were peculiar, most of them restricted to the Archipelago and many of them found only on individual islands. The beetles were referred to specialists for study. The first species described was *Calosoma galapageium* Hope, 1837. The remaining specimens were studied by George R. Waterhouse and described in 1845. In his work, Waterhouse remarked upon their peculiarities, especially their distribution. He established two genera which were confined to the Islands. In 1852, the Archipelago was visited by the Swedish frigate, *Eugenie*, and a limited number of specimens collected by the members of its expedition were later submitted to the eminent entomologist Boheman and by him classified (1858-59). In

1875, the British H.M.S. *Petrie* visited the Islands and collected a few insects which were reported on by C. O. Waterhouse, in 1877. In 1887–1888, the United States fisheries steamer *Albatross*, visited the Islands and secured a number of insects. These, twelve in number, were listed by Martin J. Linell and published upon by L. O. Howard in 1889. Later Linell (1898) discussed these in some detail.

The next exploration of the Islands was by the extensive expedition of the California Academy of Sciences, organized in 1905. The party left San Francisco, June 28, 1905, and returned November 29, 1906, spending five months in making the journey to and from the Islands and a year in exploring them. Dr. F. X. Williams who was then a student at Stanford University was the entomologist. He collected extensively and was also assisted by other members of the expedition. As a result, a fairly large collection was made, much the largest ever secured in the Galapagos Islands. In 1907, F. X. Williams made a short report on the insects in which he listed 150 species collected on the Islands. A tiger beetle collected by Williams was described by Dr. Walther Horn (1920) as *Cicindela galapagoensis*. It had been submitted to him for his opinion. These two reports are the only ones in which the Coleoptera secured by the California Academy Expedition have been mentioned so far.

Since the expedition of the California Academy of Sciences, the Galapagos Islands have been visited by various parties and collections of Coleoptera made. The first of these was by the New York Zoological Society and under the direction of William Beebe. The few beetles collected were presented to the American Museum of Natural History and studied by its curator of Coleoptera, Andrew J. Mutchler (1925). Later on, Mutchler (1938) published a supplementary paper which reported on material the Templeton Crocker Expedition to the Pacific Islands in 1925, secured incidentally to its ornithological work. He also included some specimens which Dr. Wolfgang von Hagen had secured on Indefatigable Island in 1935 and 1936 while making a preliminary ecological survey of the Galapagos Islands, and in addition mentioned a few odd specimens which were in various museums. Following the Mutchler papers, Dr. Kenneth G. Blair of the British Museum published two papers (1928 and 1933) containing his studies of some material collected by various expeditions and presented to the British Museum. In 1932, Mr. Templeton Crocker made another expedition to the Galapagos Islands when M. Willows, Jr., collected some Coleoptera. These were presented to the California Academy of Sciences. In the lot were five specimens from Chatham Island, April 18, 1932; four from Charles Island, May 15, 1932; four from Indefatigable Island,

May 4, 1932; and one from Albemarle Island, April 28, 1932. In 1936, Howard E. Hinton described *Ataenius arrowi* from a series of specimens in the British Museum which had been collected on James Island by Bateson and previously listed as *Ataenius cribrithorax* Bates. This is the last published reference to the Coleoptera of the Islands.

Soon after the members of the California Academy of Sciences Expedition returned to San Francisco, I took charge of the Coleoptera collected on the Islands, had them mounted and labeled, and proceeded to study them. There were many interruptions, chiefly through lack of time, so the study lagged. Meanwhile I was given the necessary opportunity to visit the British Museum of Natural History, in 1932-1933, and study the Darwin types described by G. R. Waterhouse and others, as well as all other specimens received by the Museum from the Galapagos Islands in more recent years. In this work I was aided by the curators of the Museum: Dr. Arrow, Dr. Blair, and Sir Guy Marshall, in particular. I also received from the authorities of the Museum through the curators, a number of specimens on loan. Later on, I visited the American Museum of Natural History in New York where, through the courtesy of Mr. Andrew Mutchler the curator, I was able to study their material. I now have before me the extensive collection of Galapagos Islands Coleoptera collected by Dr. F. X. Williams and some few additional beetles from one of the Templeton Crocker expeditions as well as paratypes and loaned specimens received through Dr. Blair of the British Museum, and Mr. Mutchler and Dr. Mont Cazier of the American Museum of Natural History. With this material I feel that I will be able to recognize and place most of the species.

I have had assistance from many people and to each and all I wish to give thanks, particularly the staff of the museums mentioned above, the authorities of the California Academy of Sciences, and Dr. F. X. Williams who is now an honorary member of the staff of the Academy and available for questioning. The drawings for the plates which accompany my paper have been made by Miss O. F. Tassart of the British Museum staff and Mrs. Freda Abernathy of the University of California. Miss Tassart did the six figures of *Calosoma* and their wings, including the type of Hope's *Calosoma galapageium*. Mrs. Abernathy made the remaining drawings.

For details of the Academy's expedition, one should consult the very full report by Joseph R. Slevin (1931).



## Family **CICINDELIDAE**

But two members of this family have been reported from the Galapagos Islands: *Cicindela galapagoensis* W. Horn, and *Cicindela vonhageni* Mutchler.

### ***Cicindela galapagoensis* W. Horn**

Plate I, figure 2

*Cicindela galapagoensis* (Van Dyke *in litt.*) W. HORN. 1915, Genera Insectorum, Fasc. 82, pp. 52, 238, 241, 251, 397, 399, 402; 1920, Archiv. für Zoologi, XIII, no. 11, p. 17.

*Cicindela galapagoensis* W. Horn, MUTCHEER, 1925, Zoologica, V, no. 20, pp. 221-222.

Of moderate size, somewhat narrow, the head, prothorax and to a great extent the meso- and metasternal areas aeneo-cupreous, the elytra in great part and the abdomen beneath more or less piceous, the antennae, mouthparts including labrum, legs, margins of the elytra, and discal markings testaceous with the exceptions of the apices of the mandibles, tibiae and tarsal segments which are rufo-piceous and the second antennal segments and apices of third and fourth antennal segments which are piceous. Head transverse, the eyes very prominent, mandibles long, clypeus broad, rather narrow antero-posteriorly and with a small tooth at the middle of the anterior margin; the occipital and frontal area rather finely rugose, somewhat strigose close to the eyes, and glabrous; the genae finely strigose beneath; and the antennae delicate and extending to about middle of elytra. Prothorax subcylindrical, feebly broader than long, slightly more than two-thirds breadth of head, the anterior margin lobed, the posterior feebly bisinuate, the sides narrowly constricted in front, broadly rounded at anterior angles, then almost straight and gradually convergent backwards; the disc with median longitudinal and anterior and posterior transverse impressions well defined, and general surface finely rugose and metallic. Elytra three-sevenths longer than broad, humeri but moderately prominent, sides almost straight, feebly divergent until near apex, then obliquely convergent and at apex transverse with a minute tooth at suture; the disc shallowly but closely and conspicuously punctate-rugose, with a greasy aspect, piceous with the lateral margins and apices broadly testaceous, and three transverse testaceous markings extending inwards from the lateral margin as follows: the stub of the humeral lunule, slightly back of the humerus, a narrow median bar extending half way to suture then continuing backwards after a right-angled turn in a slightly arcuate manner for a short distance, and near

apex the anterior portion of the apical lunule. Undersurface somewhat smooth and finely, sparsely pubescent along sides of body back of head. Legs long and delicate. Length 10 mm., breadth (of elytra) 4 mm.

Type in Dr. Walther Horn's collection on deposit in the Deutsches Entomologisches Institut at Berlin Dahlem. The remainder of the specimens belong to the California Academy of Sciences. Specimens will, however, be deposited in the British Museum of Natural History, U. S. National Museum, and American Museum of Natural History. The two specimens given to Dr. Horn and upon which he based his description belonged to a series of twenty-six specimens, all of which were collected at night, by F. X. Williams, near the shore of Banks' Bay, Albemarle Island, April 10, 1906. The species is fully winged and quite distinct from any known species, though according to Dr. Horn is more or less related to *C. bifasciata*, a species which with its varieties ranges along the west coast of the northern portion of South America, Central America, and North America as far north as middle California, and along the coast of the Gulf of Mexico. It has also been taken on Clipperton Island. The Galapagos Islands specimens were supposedly derived from the primitive *C. bifasciata* stock.

### ***Cicindela vonhageni* Mutchler**

*Cicindela vonhageni* MUTCHLER, 1938, American Museum Novitates, no. 981, May 12, pp. 2-5, pl. 1, fig. 1.

There are no specimens in the material at hand which represent this species.

### Family **CARABIDAE**

This family is represented in the Islands by numerous genera and species, some of which are quite conspicuous. They are all confined to the Islands.

### ***Calosoma howardi* Linell**

Plate I, figure 1

*Calosoma galapagoum* HOPE, LINELL, 1889, In Annot. Cat. by L. O. Howard, Proc. U. S. Nat. Mus., XII, p. 191.

*Calosoma howardi* LINELL, 1898, Proc. U. S. Nat. Mus., XXI, no. 1143, p. 251.

*Calosoma howardi* LINELL, MUTCHLER, 1925, Zoologica, V, no. 20, p. 223.

*Calosoma howardi* LINELL, CSIKI, 1927, Coleopt. Cat., pars 91, p. 12.

*Calosoma galapageium* HOPE, BREIHING, 1927, Koleopt. Rundschau 13, p. 140.

*Calosoma howardi* LINELL listed as synonym of *C. galapageium* HOPE.

*Calosoma howardi* LINELL, BLAIR, 1933, Ann. and Mag. Nat. Hist., ser. 10, vol. XI, p. 472.

Of moderate size, somewhat robust and slightly elongated; black, the upper surface more or less bright bluish green in color, the propleurae dull blue, antennae, palpi and tarsi somewhat rufous; wings fully developed and functional. Head across eyes two-thirds breadth of prothorax, front obsoletely and sparsely punctured, longitudinally strigose near eyes; eyes prominent; mandibles well developed and coarsely strigose on upper face; antennae reaching to middle third of elytra, basal segments piceous, outer somewhat rufous. Prothorax with breadth one-third greater than length, subcordate, widest in front of middle, sides evenly arcuate in front, obliquely and slightly sinuate behind and margined with a fine bead, base feebly arcuate at middle, sinuate near hind angles which are rectangular; disc moderately convex, not depressed at sides, smooth or obsoletely, finely rugose, median longitudinal impression fine yet distinct; anterior transverse impression obsolete, basal transverse impression broad, shallow and obscurely punctate, basal foveae near hind angles well impressed. Elytra over one-third longer than broad and slightly less than one-third broader than prothorax, humeral area pronounced though rounded, sides slightly arcuate and expanding to posterior third, then evenly rounded to apices; disc moderately convex, striae regular and more or less well impressed throughout, finely and somewhat closely punctured, distinctly so near base and suture, more or less obsoletely towards sides and apex; marginal striae with muricate punctures, intervals of disc convex more depressed and obsoletely transversely rugose towards the sides, the fourth, eighth and twelfth interrupted by numerous small, shallow foveae for their entire length, each fovea with a minute aciculate puncture. Ventral surface smooth, sides of metasternum and first ventral segment with more or less numerous coarse punctures. Posterior trochanter oval, alike in the sexes. Legs black, tibiae finely spinose, the intermediate ones markedly arcuate in the males, almost straight in females, with coarse and dense orange-red pubescence along the exterior groove below the middle and on the inner face near the apex. Length 15-21 mm., width 7.5-10.5 mm.

*Male:* Anterior tarsi with first three segments strongly dilated and spongy beneath. Intermediate tibiae strongly arcuate, the apex expanded, with dense orange-red pubescence beneath on inner side, and prolonged into a short obtuse spine.

*Female:* Similar to male but with anterior tarsi undilated and not spongy beneath, the intermediate tibiae straight or but feebly arcuate and without tuft of pubescence near apex nor with apices prolonged as a spine.

*Type:* No. 1311, U. S. National Museum.

The *Albatross* expedition of 1888, collected two specimens on Duncan Island and twelve on Chatham Island, and in 1888 and 1891 collected seventy-eight on Charles Island; Dr. G. Baur also collected this species on Charles Island. The Harrison Williams Expedition took one specimen on James Island, April 5, and one on South Seymour, April 23. The California Academy collection has a series of eighty-three mounted specimens from its expedition of 1905-1906, and fourteen from the Templeton Crocker Expedition of 1932. The specimens from the Academy's expedition were all collected by F. X. Williams and in the following localities: Chatham Island, January and February 1906; Charles Island, March 1906; Tagus Cove, March 22 and April 20, 1906, and Bank's Bay, April 18 and 19, 1906, both on Albemarle Island. The Academy also has specimens of elytra from Indefatigable Island, picked up November 5-16, 1906; Culpepper, September 25, 1905; and Barrington Island, October 19-24, 1905. The Templeton Crocker Expedition secured five specimens on Chatham Island, April 18-23, 1932; four on Charles Island, May 15, 1932; four on Indefatigable Island, May 4, 1932; and one on Albemarle Island, May 28, 1932.

The species as indicated by the collections is thus to be found on most of the islands, frequents the lowlands during the springtime and disappears during the summer. It is provided with fully developed and functional wings and, according to observers, flies well. Though fairly common and widespread, it was not found by Darwin, probably because his visit was not in the right season. The species as shown by the large series is fairly stable, fresh specimens being brilliant and older specimens somewhat rubbed and duller in appearance. They, however, vary as to size, our smallest specimen (Chatham Island) being but 15 mm. in length, whereas our largest are fully 21 mm. long. The wings of all specimens, large and small, which were examined were found to be fully developed. This species is probably of the primitive stock from which all species of the genus on the Islands have originated. It is a very distinct species, probably most closely related to *C. rufipennis* Dejean of Peru and northern Chile, with which it and the other Galapagos Island species are placed by Usiki in the sub-genus *Camcdula* Motschulsky in the "Coleopterorum Catalogus." It is most decidedly not a synonym of *C. galapageium* Hope as indicated by Breuning in his monograph of the genus (1927) as I will show later. It will be noted that my description based on typical specimens differs slightly from that of Linell. I count the sutural interval as the first, therefore make the first broken interval the fourth rather than the third.

**Calosoma darwinia** Van Dyke, new species

## Plate 1, figure 3

Somewhat smaller and narrower than *C. howardi*, with the elytra more narrowed towards the base and the humeral area less developed or angulated but more rounded, the upper surface faintly bronzed, the greenish areas more limited to the depressions such as the elytral striae, and the appendages lighter in color, rufous with the femora rufopiceous, and the general body color piceous rather than black, the wings normal size and not functional. Head across eyes slightly more than two-thirds breadth of prothorax; front finely, sparsely punctured and rugose, strigose near eyes; eyes prominent; mandibles well developed and coarsely strigose on upper face; antennae reaching to middle third of elytra. Prothorax with breadth two-fifths greater than length, subcordate, widest in front of middle, sides arcuate, somewhat broadly so in front, more shallowly behind as well as oblique and convergently narrowed posteriorly, base feebly and broadly arcuate at middle, sinuate near hind angles which are rectangular, disc moderately convex, not depressed at sides, median longitudinal depression fine and well impressed, apical and basal transverse impressions more or less obsolete, the general surface somewhat smooth. Elytra considerably more than one-third longer than broad and about one-third broader than prothorax, humeral area rounded and narrowed, the elytra gradually widening to posterior third then evenly rounding to apices; the disc convex, finely and moderately striate with fine, rather close and distinct punctures in the striae, the intervals convex, with the fourth, eighth and twelfth interrupted as in *C. howardi*. Ventral surface smooth, sides of metasternum and first ventral segment with a number of coarse punctures. Legs as in *C. howardi*. Length 17 mm., breadth 12.5 mm.

*Holotype*, allotype, and numerous designated paratypes from a series of seventy-five mounted specimens in the collection of the California Academy of Sciences. These were all collected at an altitude of 1300 feet, near **Villamil, Albemarle Island**, August 20–September 5, 1906, by F. X. Williams. Paratypes will be sent to the British Museum of Natural History, the American Museum of Natural History, and the U. S. National Museum.

This interesting species is somewhat smaller than *C. howardi*, proportionally narrower, more gracefully moulded, with the humeral area narrower and more obliquely rounded, the color a bronze green, and the true wings much reduced in size, though variable as to degree in different specimens, but in general about two-thirds normal length and thus not functional. This species has no doubt been derived from the

*C. howardi* stock but it has gradually diverged through time as a result of isolation being restricted to the higher altitudes of Albemarle Island which are amply supplied with moisture throughout the year, thus does not make its appearance until late summer, whereas *C. howardi* apparently generally appears during the early spring when the coastal areas and lower slopes of the islands receive their scanty rainfall. It has thus been isolated both by altitude and time of appearance and to my mind serves as an excellent example of what isolation, no matter how produced, can accomplish in the way of evolution. It, therefore, seems fitting that it should bear the name of Darwin who first received his suggestions as to the factors of evolution in these islands.

### ***Calosoma galapageium* Hope**

Plate I, figure 6

*Calosoma galapageium* HOPE, 1838, Trans. Ent. Soc. London, II p. 130.

*Calosoma howardi* LINELL, 1898, Proc. U. S. Nat. Mus., XII, no. 1143, p. 191.

*Calosoma linelli* MITCHLER, 1898, listed as *Calosoma galapageium* Hope by Linell, Proc. U. S. Nat. Mus., XXI, no. 1143, p. 250.

*Calosoma galapageium* HOPE ROESCHKE, 1900, Ent. Nachr., XXVI, p. 57.

*Calosoma galapageium* HOPE, CSIKI, 1927, Coleopterum Catalogus, pars. 91, p. 12.

*Calosoma galapageium* HOPE, BREUNING, Oct. 1927, Koleopt. Rundschau, 13, pp. 140, 149.

This species as indicated by the figure carefully drawn from the type and to scale, is considerably smaller than *C. howardi* and somewhat smaller and much narrower than *C. darwinia*. It is moderately elongated, with much reduced humeri and as a result almost certainly with even more reduced wings than in *C. darwinia* and of course non-functional; is black, with appendages rufopiceous, the upper surface more or less virido-cyanaceous, especially about posterior prothoracic depressions, in the striae and along the lateral margins. The prothorax is narrower than in *C. darwinia*, the sides posteriorly straight and convergent; the elytral striae are regular but less impressed and the striae punctures somewhat obsolete ("Elytra obsolete striata" *vid.* Hope); the fourth, eighth and twelfth intervals being interrupted in the same manner as in the two preceding species. The undersurface and legs are also similar except that the middle tibiae seem to be less arcuate. Length 16 mm., breadth 7 mm.

Type in British Museum of Natural History and at the time of my visit to the Museum in 1932-1933, was the only specimen known. It was "captured in the central part of one of the islands of the Galapagos Archipelago" (Hope). Recently while examining the duplicate

alcoholic specimens, I found a second and typical specimen of this species. It was collected on the summit of James Island, between December 24, 1905, and January 5, 1906, by F. X. Williams. This establishes the locality of the species, I think, for Darwin camped for several days in the interior of James Island. "October 8th—We arrived at James Island: ——— Mr. Bynoe, myself, and our servants were left here for a week, with provisions and a tent, while the *Beagle* went for water." Several members of the Academy Expedition also remained for several days on this island.

This species, the type of which I examined while at the British Museum, appeared when compared with typical specimens of *C. howardi* and *C. darwinia* to be quite different from either and very different from *C. linelli* with which Linell confused it. It shares with *C. darwinia* and *C. linelli* the abortive wings and like them dwells in the interior of one of the islands and at higher altitudes in the wet belt.

### **Calosoma linelli** Mutchler

Plate I, figure 7

*Calosoma linelli* MUTCHLER, 1925, Zoologica, V, p. 221.

*Calosoma galapageium* LINELL (not Hope), 1898, Proc. U. S. Nat. Mus., XXI, p. 250.

To the description given by Linell for what he took to be *C. galapageium*, but which was later found to be distinct on comparison by Blair, and later designated as *C. linelli* by Mutchler, I can merely add a few notes. First, I consider the sutural intervals to be the first, the interrupted intervals are thus the fourth, eighth, and twelfth, not the third, seventh, and eleventh. The mandibles are also much more finely strigose. The female has the anterior tarsi not dilated and the middle tibiae almost straight and without the tuft of silken hair at inner apex. The wings in this species are but the merest rudiments, as would be expected.

The specimen upon which Linell based his description and which was later designated as the type of *C. linelli* by Mutchler, is now in the U. S. National Museum. It was collected by Dr. G. Baur on Chatham Island. The California Academy of Sciences has three specimens of the same species, two males and a female, one pair collected at an altitude of 1100 feet, on Chatham Island, February, 1906, by F. X. Williams. The third specimen was also taken on Chatham Island but in January, 1906. One male has been carefully compared with the type by me and found to agree exactly.

This species as shown by the figure and description, is the most

divergent of the Galapagos Islands species of *Calosoma*. It is much smaller than the others, of a bronze color with ferruginous appendages, the upper surface with the sculpturing much reduced or planed off though with the interrupted intervals conspicuous, and the wings reduced to mere rudiments. It should also be noted that it is from Chatham Island, the most isolated of the larger islands, therefore has probably had a longer time in which to be modified.

***Scarites galapagoensis* Linell**

Plate II, figure 1

*Scarites galapagoensis* LINELL, 1898, Proc. U. S. Nat. Mus., XXI, no. 1143, pp. 253-254.

*Scarites galapagoensis* Linell, MUTCILLER, 1925, Zoologica, V, no. 20, p. 234.

The California Academy of Sciences has seven specimens, all collected on Chatham Island, during July, 1906, by F. X. Williams. They are all slightly smaller than the type, averaging about 20 mm. in length, but are otherwise in agreement. The Academy also has the remains of another specimen, the afterbody, picked up in January, 1906, which is the remains of a much larger specimen, no doubt one fully as large as the type.

***Scarites williamsi* Van Dyke, new species**

Plate II, figure 3

Elongate, parallel, moderately convex above, shining black, antennae, palpi and legs rufopiceous, apterous. Head, excluding mandibles, one-fifth broader than long, occiput smooth, impunctate, front deeply longitudinally bisulcate in front, clypeus emarginate anteriorly and with two tubercles in front, labrum irregularly arcuate in front and with three punctures, the median bisetose and the lateral unisetose, the mandibles prominent, one-fourth length of head, arcuate and acute at apex, bicarinate above, the inner carina narrow and well elevated, nonstriate within; eyes prominent, truncate behind against the equally prominent tempora; antennae extending back to hind angles of prothorax, basal segment longer than three following united, second and third over twice as long as broad, the second a bit shorter, fourth slightly longer than broad, 5-10 subequal and with terminal segment longer, compressed and pubescent; mentum similar to mentum of preceding species but with median carina more pronounced and the foveae on either side deeper and the paragenae much broader. Prothorax slightly wider than head, over two-fifths broader than long, apex broadly and shallowly emarginate and rounded at outer angles so



lateral bead does not reach the arch, sides feebly arcuate and convergent backwards to small dentate hind angles, the base pedunculate at middle and with outer portions almost transverse; the disc smooth, the median and anterior transverse lines distinct, obsoletely transversely strigose on either side of middle. Elytra somewhat shorter than forebody, almost three-eighths longer than broad, much narrower than the prothorax, humeri dentate, sides feebly arcuate, disc with striae well but not deeply impressed and with obsolete yet faintly observable fine punctures, the intervals moderately convex, the wings very rudimentary. The abdomen somewhat finely rugose, otherwise the underside and legs much as in *S. galapagoensis*. Length 18 mm., breadth 5.5 mm.

*Holotype* and numerous designated paratypes from a series of twenty-one specimens, all collected by F. X. Williams at an altitude of 100–1400 feet, near Villamil, Albemarle Island, between August 20 and September 5, 1906. Paratypes will be deposited in the British Museum of Natural History, American Museum of Natural History, and U. S. National Museum.

This species differs in many regards from *S. galapagoensis* but chiefly in having longer and smoother mandibles, a much larger and proportionately wider head, a prothorax much broader than elytra, quite short and with oblique sides, whereas the other is but little broader than long and with almost parallel sides, and elytra subelliptical as compared with the somewhat elongate and subcylindrical elytra in the other, and the striae and intervals less defined, the intervals in this species being but slightly convex whereas subcarinate in the other. There is not much variation as to length among the members of the series but considerable variation as to the breadth of head and prothorax. The smallest specimen is 18 mm. in length but has a head only 3.5 mm. broad and a prothorax but 4.5 mm. broad.

### ***Bembidion galapagoensis* (G. R. Waterhouse)**

*Notaphus galapagoensis* G. R. WATERHOUSE, 1845, Ann. Nat. Hist., XVI, p. 23.

*Notaphus galapagoensis* G. R. Waterhouse, C. WATERHOUSE, 1877, Proc. Zoo. Soc., VI, p. 81.

*Notaphus galapagoensis* G. R. Waterhouse, LINELL, 1898, Proc. U. S. Nat. Mus. XXI, no. 1143, p. 255.

*Notaphus galapagoensis* G. R. Waterhouse, MUTCHLER, 1925, Zoologica, V, no. 20, p. 234.

*Type* in British Museum of Natural History.

The California Academy of Sciences possesses one specimen from Abingdon Island, somewhat north of James Island. This was collected

by F. X. Williams, under a tree trunk in the damp belt just below the fern belt, at an altitude of 1700 feet, September 18-23, 1906. This specimen was carefully compared with the type in the British Museum of Natural History which had been misplaced and was only located after considerable search. According to my notes, the Abingdon Island specimen is more mature than the James Island specimen, is slightly smaller, proportionately shorter, the elytral striae also deeper forwards and more deeply punctured. The color pattern and other characteristics were the same. It seems to be but a slight variant and seeing that they were both fully winged, the species as a whole could easily be conceived to have a distribution including several islands as is the case with most fully winged beetles of the Archipelago.

***Bembidion equatoriale* Van Dyke, new species**

Rather small, somewhat elongate, slightly convex, black, the antennae, feet and elytra testaceous, the last with a small black spot on the third interval slightly in front of the middle and an irregular black one posteriorly commencing abruptly at the middle and extending backwards as a broad band three sutures wide along the suture almost to the apex and gradually widening posteriorly, also having a narrow transverse bar running from the middle outwards then obliquely backwards to the lateral margin. Head faintly aeneous, smooth and shining, with a minute puncture between the eyes and with deep oblique frontal grooves near the eyes which narrow the front forwards, the head as a whole narrower than the prothorax, the eyes prominent and antennae reaching to just beyond hind margin of prothorax. Prothorax subcordate, distinctly narrower at base than apex, about a third wider than long, apex truncate, sides broadly arcuate in front, sinuate behind, and straight and parallel just before base, hind angles rectangular, the disc convex, the median longitudinal line distinctly impressed, the anterior transverse impression vague, the basal foveae deep and with small, sharply defined carina near hind angles. Elytra oblong-ovate, slightly wider than prothorax, somewhat convex, with striae sharply defined except near apex and finely and closely punctured, the intervals flat, the third with first dorsal puncture one-third distant from base, the second about one-third distant from apex. Beneath black and shining. Length 3.25 mm., breadth 1.5 mm.

*Holotype* and five paratypes all collected on **Chatham Island**, January, 1906, by F. X. Williams. This species is very close to the common North American *B. versicolor* Leconte and quite different from the preceding species which seems to simulate the North American *B. variegatum* Say.

**Tachys beebei** Mutchler

*Tachys beebei* MUTCHLER, 1925, Zoologica, V, no. 20, pp. 223-224, fig. 42.

Neither of the California Academy of Sciences expeditions secured specimens of this species. A paratype has, however, been presented to the Academy by the American Museum of Natural History.

Genus **Feronia** Latreille

Three species of this genus have been described from the Galapagos Islands: *F. calathoides* G. R. Waterhouse, *F. galapagensis* G. R. Waterhouse, and *F. insularis* Boheman. The California Academy of Sciences Expedition secured eight species. Inasmuch as the descriptions of the described species did not designate particular islands and were of such a general nature that they would apply to several species, it was impossible to recognize just which were the described species from among the specimens in our collection until I had the opportunity to study the Waterhouse types in the British Museum of Natural History. These were found to be in good condition so definite determinations could be made for those species. The Boheman type is presumably in Stockholm. I was not able to study it so have been compelled to rely upon the description and thus have only tentatively placed that species. Though the eight known species fall into minor groups which will be indicated in the table, they are all more or less closely related, several very much so. They all belong to the subgenus *Poecilus* Bonelli and are all definitely flightless, possessing but the merest rudiments of wings. Each species is restricted to a single island though a single island may possess two or more species. A moderately close relationship is shown to mainland forms, one in particular being very near *F. peruvianus* Dejean, as will be discussed more in detail later on.

**Feronia calathoides** G. R. Waterhouse

Plate II, figure 6

*Feronia calathoides* G. R. WATERHOUSE, 1845, Ann. Nat. Hist., XVI, p. 21.

*Feronia calathoides* G. R. Waterhouse, C. WATERHOUSE, 1877, Proc. Zoo. Soc., V, p. 82.

*Poecilus calathoides* G. R. Waterhouse, GEMMINGER and HAROLD. Cat. Col., I, 1868, p. 300.

*Poecilus calathoides* G. R. Waterhouse, HOWARD, 1889, Proc. U. S. Nat. Mus., XII, no. 771, p. 252.

*Pterostichus calathoides* G. R. Waterhouse, LINELL, 1898, Proc. U. S. Nat. Mus., XXI, no. 1143, p. 252.

*Pterostichus calathoides* G. R. Waterhouse, MUTCHLER, 1925, Zoologica, V, no. 20, p. 234.

Oblong-ovate, shining black; antennae, palpi, tibiae, tarsi and hind margin of abdomen rufous, femora rufopiceous. Head triangular, smooth except for a few minute punctures and vague strigae at vertex, eyes moderately prominent, antennae reaching beyond hind angles of prothorax. Prothorax over one-seventh broader than long, base broadly emarginate, apex emarginate, sides almost straight or feebly arcuate to beyond middle then gradually arcuately narrowed forwards, anterior angles rounded and slightly extended forwards, the hind angles right angled but blunt, the side margin a fine bead, the base obscurely margined, the disc feebly convex in front, much flattened behind, the median longitudinal line finely impressed, the anterior and posterior transverse impressions absent, the basal impressions sharply impressed, linear and feebly convergent forwards, a marginal seta one-third distance from apex and another near hind angles. Scutellum broadly triangular. Elytra twice as long as broad, equal to base of prothorax at point of contact, obliquely widening for short distance, then feebly arcuate and gradually narrowing to near apex where more suddenly rounded and sinuate to apex; the disc considerably flattened, the sides somewhat explanate, the striae sharply and deeply impressed and impunctate except the eighth, the intervals feebly convex, the third with three dorsal punctures (one or more sometimes absent), one near third stria a short distance from base, the second at middle and near second stria and the third at apical fourth and also near second stria. Underside smooth and somewhat dull, prosternum not margined behind. Length 11 mm., breadth 4.25 mm.

Type and four other specimens in the British Museum of Natural History, several received in 1845, others later, but presumably all collected by Charles Darwin on the Galapagos Islands.

The California Academy of Sciences has four specimens of this species, all collected by F. X. Williams on Chatham Island, in January, 1906, at a moderate altitude in a damp locality. One of these specimens I carefully compared with the type in the British Museum of Natural History and found it to agree in every regard, thus establishing the exact locality. As stated by G. R. Waterhouse, this species very much resembles *Calathus*, particularly *Calathus cistelloides*.

#### ***Feronia waterhousei* Van Dyke, new species**

Very similar to the preceding, the main differences being that it is proportionally shorter, therefore more broadly elliptical in outline; the prothorax narrower at base, thus more equally quadrate, the sides more evenly arcuate, practically arched from base to apex; and the sides of elytra more definitely and evenly arcuate as well.

*Holotype* and one slightly injured paratype; the first collected in March, 1906, and the second June 1, 1906, on **Charles Island**, by F. X. Williams. Both were collected in the interior on the mountains.

### **Feronia insularis** Boheman

*Feronia insularis* BOHEMAN, 1858, Fregatten Eugenies Resa, I, p. 14.

*Feronia insularis* Boheman, C. WATERHOUSE, 1877, Proc. Zoo. Soc., p. 82

*Feronia insularis* Boheman, LINELL, 1899, Proc. U. S. Nat. Mus., XXI, p. 255.

*Feronia insularis* Boheman, MUTCHLER, 1925, Zoologica, V, no. 20, p. 234.

Elongate, oblong, shining black; antennae, mouthparts, tibiae and tarsi rufous, the femora rufopiceous. Head moderately elongate, minutely alutaceous above and very finely, sparsely punctate and obscurely strigose at vertex; eyes rather large in circumference but considerably flattened; antennae reaching well beyond hind angles of prothorax. Prothorax less than one-third broader than long, base broadly yet feebly emarginate, apex emarginate, sides almost straight and feebly convergent to beyond middle then gradually arcuate to apex, front angles, rounded and slightly extended forwards, hind angles right but blunt, side margin finely reflexed, basal margin faintly defined outwardly; disc flattened, median longitudinal line finely impressed at middle, anterior transverse impression vaguely defined, basal impressions well marked but not as sharply defined as in *F. calathoides*, and marginal setae one-third distance from apex and near basal angles as usual. Elytra one-third longer than broad, as wide at base as prothorax, gradually arcuately wider for a short distance backwards, almost straight at middle and feebly convergent to posterior third, then more arcuate, narrowed, and strongly sinuate near apex; the disc feebly convex, the striae sharply and distinctly impressed and impunctate, the intervals feebly convex and shining in males, flattened and alutaceous in females, feebly alternately wider in both sexes and with three dorsal punctures, the basal on third stria one-fourth distance from base, the second close to second stria at middle and third also close to second stria one-fourth distance from apex. Undersurface dull and piceous or feebly rufopiceous, the prosternum feebly margined behind. Length 10 mm., breadth 4 mm.

*Type*, supposedly in Stockholm Museum.

The species that I have tentatively identified as *F. insularis* Boheman is a medium sized black and somewhat narrow species from Albemarle Island. The California Academy of Sciences has fifty-six specimens of this species, all collected by F. X. Williams **near Villamil, Albemarle Island**, between August 20 and September 5, 1906, from beneath moss.

**Feronia blairi** Van Dyke, new species

Robust, elongate, aeneous or deep bluish black and shining, antennae and palpi rufous, legs and epipleurae rufopiceous. Head smooth except from obsolete strigae and minute punctures on front, frontal impressions marked, the fronto-clypeal suture less distinct, eyes prominent. Prothorax very slightly broader than long (superficially looks longer in type), widest in front of middle, apex broadly emarginate, base feebly emarginate at middle, sides evenly arcuate from apex to slightly back of middle thence almost straight and convergent to subacute and feebly obtuse hind angles, the setiferous punctures present in type but absent in paratypes; disc convex in front, flattened behind, median longitudinal line finely and sharply impressed, transverse impressions obsolete or only faintly indicated in front, basal impressions long, linear and well impressed, the base vaguely margined at sides, flattened between basal impressions and side margins and obsoletely strigose at middle. Elytra about one-third longer than broad, broadest at middle, humeral angles obtuse, sides arcuate from humeri to apical sinuation but feebly so at middle; the disc moderately convex, rather deeply striate, striae impunctate, intervals convex near apex, flattened in front and minutely alutaceous even in males, dorsal punctures three, the first on third interval near third stria just back of base, the second on third interval close to second stria and about the middle, the third also on third interval and near third stria and a little less than a fourth from the apex, the eighth stria with the usual ocellate foveae. Beneath smooth and shining, the apex of prosternum finely margined behind. Length 11.5 mm., breadth 4.25 mm.

*Holotype* male and two paratypes, the first collected by F. X. Williams on **James Island**, between December 20, 1905, and January 5, 1906. The two paratypes were collected by G. Bateson on James Island, February 20-22, 1925, and were from a series of fourteen specimens in the British Museum of Natural History. The *holotype* is in the collection of the California Academy of Sciences. One paratype of the two which were kindly submitted for comparison by Dr. K. G. Blair, will be returned to the British Museum of Natural History.

This species is much like *F. williamsi* but is absolutely and proportionally more elongate, the prothorax and elytra individually noticeably so, the prothorax also widest well in advance of the middle and with side margins straight behind. It is also very distinct from *E. galapagoensis*, which is likewise found on James Island. Superficially it resembles *F. peruviana* Dejean, a mainland species, but differs by having a narrower pronotum.

**Feronia mutchleri** Van Dyke, new species

Moderately elongate and narrow, black, shining in males and subopaque in females; the antennae and palpi rufous, the legs and to a slight extent, the epipleurae rufopiceous. Head smooth, alutaceous under good magnification, with faint strigosities and minute punctures on front as well as on clypeus and labrum, the frontal impressions and fronto-clypeal suture well marked, and eyes prominent. Prothorax subquadrate, slightly broader than long, widest in front of middle, apex and base at middle feebly emarginate, sides slightly arcuate from apex to back of middle thence straight and convergent to hind angles which are feebly obtuse and with distinct setiferous punctures, apex but little narrower than base; disc convex in front, flattened behind, median longitudinal line finely and sharply impressed, transverse impressions obsolete, basal impressions long, linear and deep, base finely margined at sides, flattened near hind angles, and vaguely strigose at middle. Elytra slightly less than one-third longer than broad, widest at middle, humeral angles obtuse, sides moderately arcuate from humeri to apical situation; the disc moderately convex, striae sharply but not deeply impressed, impunctate, intervals convex near apex, flattened in front, minutely alutaceous in both sexes though more evident in females, shining in males and subopaque in females, dorsal punctures as in preceding species, the eighth striae with usual ocellate foveae. Beneath smooth and shining, the apex of prosternum finely margined. Male, length 10.5 mm., breadth 3.5 mm.; female, length 11 mm.; breadth 4 mm.

*Holotype* male, allotype female and five paratypes. The first two were collected **near Villamil, Albemarle Island**, in March, 1906, by F. X. Williams. Four of the others were collected at Tagus Cove, Albemarle Island, April 1, 1906, by F. X. Williams and one at Banks Bay, Albemarle Island, April 10, 1906, also by Williams. This species is the smallest found in these islands, in features midway between *F. blairi* and *F. galapagensis* and having in common with them the prothorax widest in front of middle and the elytra somewhat bulbous at the apex of the declivity, feeble in the first and well marked in the second. Its most distinctive features are the somewhat shining black color, more or less quadrilateral prothorax and small size. It also differs markedly from *F. insularis* and other Albemarle species, which have a somewhat cuneate prothorax, broadest behind, and elytra that are much broader and somewhat cordiform.

**Feronia duncani** Van Dyke, new species

Plate II, figure 4

Robust, elongate, elliptical and of a deep bluish black color, the antennae and palpi rufous, and the legs rufopiceous. Head smooth except for a series of very minute punctures on front, the frontal impressions deep, the fronto-clypeal suture well marked, eyes prominent. Prothorax subquadrate, slightly broader than long and widest at middle, apex broadly emarginate, base emarginate at middle, sides evenly arcuate, somewhat narrowed towards apex, hind angles somewhat obtuse and blunt; the setae and setiferous punctures generally absent; disc slightly convex in front, flattened behind, median longitudinal line fine and sharply impressed, transverse impressions obsolete, basal impressions deep and linear, one-fourth as long as the prothorax, the base at most with an obscure margin, but finely strigose near center. Elytra about one-third longer than broad, broadest one-fourth back of base, humeral angles subrectangular, sides rather evenly arcuate, gradually narrowed towards apex and slightly sinuate before it; the disc convex, deeply striate, the striae impunctate, intervals rather evenly convex throughout and minutely alutaceous especially in females, the dorsal punctures three, the first on third interval near third stria just back of base, the second on third interval close to second stria and about the middle, the third also on third interval and near third stria and a little less than a fourth from apex, the eighth stria as usual with numerous ocellate punctures. Beneath smooth and shining, the apex of prosternum sharply margined. Length 12 mm., breadth 4.75 mm. (of types).

*Holotype* male, allotype female and numerous designated paratypes from a series of a hundred and forty-eight specimens collected from beneath moss, in the interior of **Duncan Island** at an altitude of 1280 feet, between the dates of December 1 and 17, 1905, by F. X. Williams. There is some variation in size, the smallest specimen being 10.5 mm. long and the largest 13.5 mm. long.

This species is quite a typical representative of the subgenus *Poecilus* and rather closely related to *Feronia (Poecilus) peruviana* Dejean, and allies from the mainland. It differs, however, in general, by having the striae more deeply impressed and the intervals more convex.

**Feronia williamsi** Van Dyke, new species

Robust, elongate, elliptical, a faint bluish black color or somewhat aeneous in the female, the antennae and palpi rufous and legs rufo-



piceous. Head smooth except for somewhat obsolete strigae and very minute puncture on front, frontal impressions and fronto-clypeal suture well marked, eyes prominent. Prothorax subquadrate, very slightly broader than long, broadest at middle or sometimes slightly in front of it (female), apex broadly and shallowly emarginate, base feebly emarginate at middle, sides evenly arcuate about equally narrowed toward front and base especially in males, hind angles obtuse and well rounded at apices and with distinct setiferous punctures; disc somewhat convex, flattened behind, median longitudinal line distinct and finely impressed, transverse impressions obsolete, basal impressions linear and well impressed, the base feebly margined at sides and minutely obsoletely strigose at center. Elytra one-third longer than broad, widest at middle, humeral angles obtuse and rounded, sides rather evenly arcuate from humeri to apical sinuation: the disc convex or feebly flattened in front, rather deeply striate, the striae impunctate, intervals convex behind, somewhat flattened in front, shining in males, minutely alutaceous and dull in females, dorsal punctures three, placed as in *F. duncani*, the eighth stria with numerous ocellate foveae as usual. Beneath smooth and shining, the apex of prosternum finely margined. Length 10.5 mm., breadth 4 mm.

*Holotype* male, allotype female and two male paratypes, the first two collected by F. X. Williams on **Indefatigable Island**, October 25–29, 1905, and January 11–12, 1906, the last two by M. Willows, Jr. of the Templeton Crocker Expedition of 1932, on the same island, May 2, 1932.

This species averages considerably smaller than *F. duncani* but is closely related to it. Its most distinctive characters are the rounded hind angles of prothorax, the more elliptical elytra with elytral intervals somewhat flattened forwards and the distinctive sexual differences both as to color and degree of dullness. This species is perhaps even more closely related to *F. peruviana* Dejean than is *F. duncani*.

### **Feronia galapagoensis** G. R. Waterhouse

Plate II, figure 5

*Feronia galapagoensis* G. R. WATERHOUSE, 1845, Ann. Nat. Hist., XVI, p. 21.

*Feronia galapagoensis* G. R. Waterhouse, C. WATERHOUSE, 1877, Proc. Zoo. Soc. V, p. 82.

*Poecilus galapagoensis* G. R. Waterhouse, GEMMINGER and HAROLD, Cat. Col. I (1868), p. 302.

*Platynus galapagoensis* G. R. Waterhouse, LINELL, 1898, Proc. U. S. Nat. Mus., XXI, no. 1143, p. 252.

*Platynus galapagoensis* G. R. Waterhouse, MUTCHLER, 1925, Zoologica, V, no. 20, p. 234.

Narrow, elongate, subparallel, bronzed or aeneous-black, beneath more or less rufopiceous, antennae palpi and legs rufous (the last sometimes piceous), the upper surface shining in the males and more or less alutaceous and dull in the females. Head much longer than broad, somewhat shining except vertex which is minutely punctured and rugose, eyes moderately prominent, antennae extending beyond hind angles of prothorax. Prothorax at least one-sixth broader than long, base shallowly and apex more evidently emarginate, sides rather evenly arcuate from apex to posterior third, thence straight or feebly sinuate and convergent to hind angles which are slightly obtuse, lateral margin finely reflexed from base to apex; disc moderately flattened, median longitudinal line distinct though not reaching either base or apex and anterior and posterior transverse impressions feeble and limited to median area, the basal impressions longitudinally arcuate but not sharply impressed though distinct, the area near hind angles much flattened. Elytra almost twice as long as broad, widest back of middle, with sides feebly arcuate anteriorly, more broadly rounded posteriorly and distinctly sinuate in front of hind angles; the disc flattened, the striae finely and sharply impressed and impunctate, the intervals flattened except toward apex where feebly convex and distinctly alutaceous especially in females; three dorsal foveae, the first on third stria, one-fourth distance from base, the second on second stria, about its middle, and the third also on second stria and one-fourth distance from apex, the ocellate punctures on eighth stria well marked, the sutural area at summit of apical declivity somewhat bullous and the area in front from second to fourth stria more or less depressed. Beneath smooth and shining, the prosternum margined behind. Length 10 mm., breadth 3.75 mm.

This species is proportionally the most elongate and narrow of any of the species from the Islands. The California Academy of Sciences has fourteen specimens from James Island, collected on various dates from December 22, 1905 to January 5, 1906, all by F. X. Williams. One of these was very carefully compared with the type in the British Museum of Natural History, by me, and found to agree exactly. This establishes the exact locality for the species, also proves that it is a true *Feronia*, not a *Platynus* as listed by Linell and Mutehler.

***Feronia galapagoensis becki* Van Dyke, new subspecies**

In the series of twelve specimens possessed by the Academy, there appear to be two quite easily separated forms. Ten specimens are in agreement with the type. They are bronzed and narrow, thus be-

longing to the true form of *F. galapagoensis*. The remaining two specimens, fortunately a pair, have a somewhat bluish bronze color, are more robust and evidently convex, with the sides of the prothorax straight and obliquely convergent behind, not sinuate, with the elytra more elliptical, broader at the middle and with sides evenly arcuate. These two I will designate as the subspecies *F. g. becki*, indicating a holotype and allotype. They were both collected on **James Island**, January 2, 1906, by F. X. Williams, and are named for the leader of the California Academy of Sciences Expedition. These may prove to be a distinct species but I would like to see more specimens as well as secure more field information before saying so. The two forms were apparently collected at the same place and at the same time. They are much alike in most essentials yet readily separated and very different from any species found elsewhere in the Archipelago.

#### KEY TO SPECIES OF GALAPAGOS ISLANDS FFRONIA LATREILLE

1. Prothorax widest posteriorly ..... 2
- Prothorax widest at middle or in front of middle ..... 4
2. Broad, somewhat flattened and elliptical species, with sharply impressed and linear basal prothoracic impressions and more or less flattened elytral intervals ..... 3
- Narrower, more parallel-sided species with distinct but not sharply impressed basal prothoracic impressions and more or less flattened elytral intervals. Albermarle Is. .... *F. insularis* Boheman
3. Prothorax with sides almost straight from base to anterior third thence evenly arcuate and narrowed forwards. Chatham Is. ....
- Prothorax with sides straight and parallel to about middle thence feebly arcuately narrowed forwards. Charles Is. .... *F. calathoides* G. R. Waterhouse
4. Prothorax widest at about the middle, bluish black in color. .... 5
- Prothorax widest in front of middle ..... 6
5. Larger species, 12 mm. or more in length, prothorax but little broader than long, with hind angles angulate and elytral intervals very convex. Duncan Is. .... *F. duncani*, new species
- Somewhat smaller species, 10 mm. in length, prothorax about a fourth broader than long, with hind angles evidently rounded and elytral intervals more or less flattened on disc. Indefatigable Is. ....
- ..... *F. williamsi*, new species
6. Elongate, subdepressed and bronzed or submetallic species with sides of prothorax posteriorly straight or feebly sinuate. James Is. ....
- ..... *F. galapagoensis* G. R. Waterhouse
- Broader and more elliptical species, moderately convex and black with sides posteriorly feebly arcuate. .... 7

7. Larger species, 11 mm. in length, bluish black with sides of prothorax rather evenly arcuate throughout. James Is.....*F. blairi*, new species  
 — Smaller species, 9 mm. in length, shining black with sides of prothorax very feebly arcuate behind or almost straight. Albermarle Is.....  
 .....*F. mutchleri*, new species

### Genus *Agonum* Samouelle

As a result of the Expedition of the California Academy of Sciences, we now know that at least three species of the genus *Agonum* are to be found in the Galapagos Islands. In his paper of 1898, Linell listed Waterhouse's *Feronia galapagoensis* as *Platynus galapagoensis*. In the first place, *Platynus* cannot be used. It is not valid as it is a *nomen nudum*. In the second place, the Waterhouse specimen is a true *Feronia* as I have stated before. I examined the type very carefully and compared some James Island specimens with it which proved to be the same. The specimen that Linell had was from Chatham Island. We have two species of *Agonum* from Chatham Island. One of these seems to fit Linell's description. It is most certainly not the same as the *F. galapagoensis* of Waterhouse.

### *Agonum darwini* Van Dyke, new species

Plate II, figures 7, 8

Large, broad and flattened, black, somewhat brownish; antennae, palpi, legs, and undersurface rufous. Head moderately elongated and smooth, frontal impressions well marked, labrum alutaceous and somewhat opaque; eyes prominent, antennae long and delicate and reaching at least three segments beyond front margin of elytra. Prothorax one-fourth wider than long, cuneate, widest at base; base transverse, apex slightly emarginate, sides arcuate from front angles to behind middle thence straight and feebly divergent to hind angles which are rectangular; disc feebly convex in front, broadly flattened towards hind angles, median longitudinal line fine and well impressed, anterior transverse impression distinct but feeble, basal impressions long and lunate and well defined, basal margin fine but rather indistinct, general surface smooth and shining but minutely alutaceous under magnification. Elytra cordate, about one-third longer than broad, widest behind humeri where almost a third wider than base of prothorax, humeri broadly rounded, sides feebly arcuate and gradually narrowed posteriorly, feebly sinuate in front of rounded or blunt apices, the lateral margin narrow and reflexed; disc feebly convex, flattened in front, striae finely and distinctly impressed, impunctate, intervals flat; the dorsal punctures three, the first on third stria at basal fourth, the second on second

stria and near apex, the general surface minutely alutaceous and sub-opaque. Beneath smooth and shining. Legs long and delicate. Length 12 mm., breadth 5.5 mm.

*Males* with slightly dilated anterior tarsi and one pair of anal setigerous punctures, the females with two pair of anal setigerous punctures.

*Holotype* male, allotype female and two female paratypes, all from **Chatham Island** and collected by F. X. Williams, January 1, 1906, the allotype, July, 1906, and both paratypes, January, 1906; one of the female paratypes has the prothorax proportionately narrower than the others. The species as a whole looks very much like some of the large, flattened species of *Calathus*.

***Agonum chathamii* Van Dyke, new species**

Plate II, figure 9

Of moderate size, rather broad, flattened, dark brown or feebly rufous, antennae and palpi rufous and legs and under surface dark rufous or rufopiceous. Head somewhat elongate, smooth and shining above, labrum somewhat opaque, frontal impressions distinct, eyes moderately prominent, antennae long and delicate and reaching about three segments back of front margin of elytra. Prothorax less than one-sixth broader than long, widest at middle, base perceptibly arcuate medially, obscurely and finely margined at most, sides rather broadly arcuate from apex to near base but then sinuate, hind angles feebly obtuse; disc somewhat convex, broadly flattened near hind angles, lateral margin fine in front, gradually broader behind and reflexed, median longitudinal line finely and distinctly impressed, anterior transverse impression obscure; basal impressions long, lunate, and well but not sharply impressed, general surface smooth and shining though like head minutely alutaceous under high magnification. Elytra elongate-cordate, somewhat over one-fourth longer than broad, widest one-fourth distance from base and over one-fourth broader than prothorax, humeri broadly rounded, sides at middle feebly arcuate, more evidently so posteriorly and gradually narrowing and feebly sinuate to blunt or slightly rounded apices, the lateral margin narrow and reflexed; disc feebly convex, striae finely and distinctly impressed, impunctate, intervals flat or very feebly convex, the dorsal punctures three and placed as in preceding species but often vague or wanting, the general surface somewhat shining though minutely alutaceous. Beneath smooth and shining. Legs long and delicate. Males, length 12 mm., breadth 4.75 mm.; females, length 12 mm., breadth 5 mm.

Males and females with similar sexual characters to preceding species.

*Holotype* male, allotype female and numerous designated paratypes from a series of thirty-nine specimens, all collected near **Wreck Bay, Chatham Island**, during February, 1906, by F. X. Williams. The specimens of the series are fairly constant in character, the females as a rule somewhat more robust than the males.

The species in most of its characteristics is somewhat like *A. darwini* but it is in general slightly narrower and with the elytral striae somewhat deeper. The prothorax is, however, very different in shape and proportions and these are diagnostic. This species, I am inclined to believe, was what was described by Linell as *Platynus galapagoensis* G. R. Waterhouse under the impression that it was what G. R. Waterhouse named and characterized as *Feronia galapagoensis* Waterhouse. *Feronia galapagoensis* Waterhouse, is, however, a true *Feronia* as I proved by studying the type in the British Museum of Natural History, and in appearance not at all like what Linell possessed.

### **Agonum albemarli** Van Dyke, new species

Rather small, moderately flattened, rufotestaceous; antennae, labrum, palpi and tarsi testaceous. Head rather elongate, smooth and shining though minutely alutaceous, frontal impressions well defined, eyes prominent, antennae delicate and reaching back of front margin of elytra. Prothorax barely broader than long, widest at middle, base feebly arcuate, apex emarginate, sides slightly arcuate in front, broadly so at middle and straight and obliquely convergent to hind angles which are strongly obtuse and rounded, the lateral margin narrow in front, broader behind and reflexed; disc feebly convex, laterally somewhat deplanate behind near hind angles, median longitudinal line finely impressed, anterior transverse impression very feeble, basal impressions indistinct, the general surface minutely alutaceous. Elytra cordate, slightly more than one-third longer than broad, widest back of humeri and over a third broader than prothorax, humeri broadly rounded, sides feebly sinuate at middle, arcuate posteriorly and gradually narrowed towards the acute apices; disc convex, striae strongly impressed, impunctate, intervals convex, the dorsal punctures three and located as in preceding species, the general surface shining though minutely alutaceous. Beneath smooth and shining. Legs moderately long and delicate. Length 9 mm., breadth 3.5 mm.

Sexual characters as in preceding species.

*Holotype*, a unique male, collected near Villamil, Albemarle Island, October 5, 1905, by F. X. Williams.

This species is probably of the same stock as the two preceding species as indicated by the cordiform elytra and minutely alutaceous integument above, but it is a very different looking insect, being much smaller, lighter in color, with a differently formed prothorax, and with more convex elytra and more deeply impressed striae. It resembles closely certain of its Holarctic relatives which the others do not.

### Genus *Selenophorus* Dejean

This is a large and typical Neotropical genus of Carabidae which extends its range north throughout Central America, Mexico, the West Indies, and into the eastern part of the United States. No species are known from the Pacific States. In the Galapagos Islands, three species are to be found, all of which are fully winged. One of these was originally placed in a wrong genus as will be shown later.

#### *Selenophorus galapagoensis* G. R. Waterhouse

*Selenophorus galapagoensis* G. R. WATERHOUSE, 1845, Ann. Nat. Hist., XVI, p. 22.

*Selenophorus galapagoensis* G. R. Waterhouse, C. WATERHOUSE, 1877, Proc. Zoo. Soc., pp. 77 and 82.

*Selenophorus galapagoensis* G. R. Waterhouse, HOWARD, 1889, Proc. U. S. Nat. Mu., XII, no. 771, p. 191.

*Selenophorus galapagoensis* G. R. Waterhouse, LINELL, 1898, Proc. U. S. Nat. Mu., XXI, no. 1143, p. 254.

*Selenophorus galapagoensis* G. R. Waterhouse, MUTCHLER, 1925, Zoologica, V, no. 20, p. 235.

Elliptical, flattened, dark piceous above with a bronzed lustre; antennae, palpi, and legs testaceous; the front of head, epipleurae, and underside in great part rufous or rufocastaneous. Head robust, but slightly convex above, finely alutaceous, frontal impressions small and illy defined, eyes prominent. Prothorax almost a third broader than long, moderately flattened, base feebly emarginate, apex rather deeply so, sides feebly arcuate in front and gradually convergent from before middle to base, front and hind angles rather broadly rounded, the latter also obtuse; disc alutaceous, less evident and more shining in males, median longitudinal line finely impressed, basal impressions vague and shallow, base finely margined. Elytra over one-third longer than broad, one-third longer than forebody, distinctly broader at base

than prothorax and with humeri well developed, the sides feebly arcuate at middle, more broadly rounded and convergent posteriorly and feebly sinuate before apex; the disc somewhat flattened, minutely alutaceous and distinctly bronzed, especially in males, the striae finely impressed, impunctate, but the second, fifth, seventh and submarginal striae with numerous well impressed foveae, the intervals flat. Beneath smooth and shining. Length 9–10 mm., breadth 3.5–4 mm.

This species is apparently common and widely spread in the Archipelago. The California Academy of Sciences has specimens from Chatham, Charles, Hood, and Gardner islands.

***Selenophorus wenmani* Van Dyke, new species**

Robust, elliptical, moderately convex above, black or dark piceous above, alutaceous and subopaque, beneath rufopiceous. Head very robust, convex above, distinctly alutaceous, frontal impressions small but distinct, the fronto-clypeal suture well impressed and the clypeus also with a transverse impression back of the apex, eyes prominent, outer antennal segments robust, about twice as long as broad. Prothorax a third broader than long, slightly convex above, finely alutaceous, base and apex feebly emarginate, sides feebly arcuate, more narrowed towards base, the hind angles obtuse and well rounded; disc with median longitudinal impression fine, the anterior transverse impression vague, the basal impressions shallow and feebly defined, the basal margin complete and distinct. Elytra one-third longer than broad, but little broader at base than prothorax, the humeri prominent, sides feebly, irregularly arcuate medially, slightly explanate back of middle and sinuate as usual near apex; disc very convex, minutely alutaceous and subopaque, striae finely impressed, impunctate, the second, fifth, and seventh with feebly impressed foveae, the submarginal with well defined foveae as usual, the intervals flat in front, feebly convex on declivity. Beneath smooth and shining. Male, length 8 mm., breadth 3.5 mm.; female, length 10 mm., breadth 4 mm.

*Holotype* male, allotype female and three paratypes, collected on Wenman Island, October 24, 1906, by F. X. Williams.

This species is the most isolated of the island species. Structurally, it stands midway between *S. galapagoensis* and *S. obscuricornis*, possessing with the former the flattened elytral intervals and with the latter the robust body, piceous and subopaque appearance, robust antennae and more or less obscure elytral foveae.



**Selenophorus obscuricornis** (G. R. Waterhouse)

Plate II, figure 2

- Amblygnathus obscuricornis* G. R. WATERHOUSE, 1845, Ann. Nat. Hist., XVI, p. 22.
- Amblygnathus obscuricornis* G. R. Waterhouse, C. WATERHOUSE, 1877, Proc. Zoo. Soc., p. 82.
- Amblygnathus obscuricornis* G. R. Waterhouse, LINELL, 1898, Proc. U. S. Nat. Mus., XXI, no. 1143, p. 255.
- Amblygnathus obscuricornis* G. R. Waterhouse, MÜTCHLER, 1925, Zoologica, V, no. 20, p. 234.
- Selenophorus obscuricornis* (G. R. Waterhouse), BLAIR, 1933, Ann. Mag. Nat. Hist., XI, ser. 10, p. 472.

Robust, very convex, black and piccous; antennae, legs and under surface generally rufopiceous; entire upper surface finely alutaceous and subopaque. Head very robust, quite convex above, frontal impressions small but distinct, the fronto-clypeal and clypeo-labial sutures very sharply marked; eyes prominent, antennae robust with outer segments about twice as long as broad. Prothorax slightly less than a third broader than long, quite convex above, base feebly emarginate, apex more distinctly so, sides evenly arcuate from apex to behind middle thence somewhat straight and convergent to hind angles which are distinct. Very obtuse and rounded at apices; disc with median longitudinal line rather distinct but with transverse impressions vague and basal impressions but feebly defined, the basal margin complete and distinct as usual. Elytra slightly less than one-third longer than broad, somewhat broader at base than prothorax, humeri prominent, sides but feebly arcuate in front, moderately explanate back of middle and rounded and feebly sinuate towards apex; disc very convex, striae deeply impressed, impunctate, the second, fifth and seventh with but vaguely impressed foveae, the submarginal with the foveae distinct as usual, the intervals quite convex and with a suggestion of carinae towards declivity. Beneath smooth and shining. Length 7.5–9 mm., breadth 3.5–4 mm.

This species is the most opaque and robust found in these islands and as such easily separated from the others. It was placed by G. R. Waterhouse in the genus *Amblygnathus* but as indicated by Blair belongs in *Selenophorus*. In the former genus as shown by an examination of the type species *A. cephalotus* Dejean, as well as *A. mexicanus* Bates, the frons is very broad and the sides do not extend forward so as to widely separate the narrowed clypeus from the eyes as is the case in *Selenophorus*. In *S. obscuricornis*, the sides of the clypeus are widely separated from the eyes by the extension forwards of the sides of the

frons and the mandibles are greatly exposed, not concealed to a considerable extent by a wide labrum as they would be in *Amblygnathus*. The California Academy of Sciences collection possesses specimens from Tagus Cove, Iguana Cove, and Villamil, Albemarle Island, all collected by F. X. Williams, at the first locality from March 22–April 20, 1906; at the second from March 17–20, 1906; and at the last from April 24–27, 1906.

KEY TO SPECIES OF GALAPAGOS ISLANDS SELENOPHORUS DEJEAN

1. Much flattened, bronzed above; elytra with flat intervals and second, fifth, and seventh striae with well-marked foveae, the ninth and tenth antennal segments almost three times as long as broad ..... *S. galapagoensis* G. R. Waterhouse
- Quite convex, piceous, distinctly alutaceous and subopaque above, the second, fifth and seventh elytral striae with less distinctly marked foveae; the ninth and tenth antennal segments hardly more than two and a half times as long as broad at most ..... 2
2. Elytral intervals flattened, the foveae observable, ninth and tenth antennal segments about two times as long as broad ..... *S. wenmani*, new species
- Very convex, elytral intervals convex, the foveae more or less obsolete, ninth and tenth antennal segments hardly more than twice as long as broad ..... *S. obscuricornis* (G. R. Waterhouse)

Family **DYTISCIDAE**

**Copelatus galapagoensis** G. R. Waterhouse

*Opelatus (?) galapagoensis* G. R. WATERHOUSE, 1845, Ann. Nat. Hist., XVI, pp. 23-24.

*Copelatus galapagocnsis* G. R. Waterhouse, C. WATERHOUSE, 1877, Proc. U. S. Nat. Mus., XXI, no. 1143, p. 255

*Opelatus galapagoensis* G. R. Waterhouse, LINELL, 1898, Proc. U. S. Nat. Mus.,  
XXI, no. 1143, p. 255

*Copelatus galapagoensis* G. R. Waterhouse. MUTHIER, 1925, Zoologica, V, no. 20, p. 235.

Elliptical, pointed behind, slightly convex, piceous, head, lateral margins of prothorax and elytra (sometimes entire elytra), antennae and legs rufotestaceous. Head obscurely alutaceous and with a series of small supraorbital punctures. Prothorax over two and a half times as broad as long, the disc piceous, obscurely alutaceous, minutely, sparsely punctured, somewhat strigose, most evident towards base and with a transverse row of coarse punctures back of the apex. Elytra eleven-striate (not counting marginal), the first, third, fifth, seventh,

and ninth practically complete, the alternate striae ending some distance before apex, and the eleventh not extending forwards much beyond the middle, the intervals flat, the sutural twice as broad as the others, minutely, sparsely punctured and obscurely alutaceous. Beneath with hind coxae finely, obliquely strigose, the rest of surface smooth and shining. Length 5-6 mm., breadth 2.5-2.75 mm.

This species is a true member of the genus *Copelatus*, having the hind tibiae ciliate even in the type female. Here they are closely adherent to the tibiae, hence overlooked by Waterhouse. The size of the species and type of striation will, I think, readily differentiate this species from any South American mainland species. The California Academy of Sciences has specimens from near Wreck Bay, altitude 800 feet, Chatham Island, July 1906; and Iguana Cove, Albemarle Island, March 1906; all collected by F. X. Williams.

### ***Rhantus signatus* (Fabricius) ?**

A single female from Chatham Island, collected on January 1, 1906, by F. X. Williams, seem to be near *Rhantus signatus* Fabricius, but according to Hugh Leech, "The single female differs from Chilean examples at hand as follows: narrower anteriorly; pronotum depressed laterally just before the side, which are more convex, more strongly and evenly margined; anterior angles of pronotum flattened and broadened, posterior angles more nearly rectangular; meshes of elytral reticulation coarser and more deeply impressed; metasternal wing narrower."

The above-mentioned species may be new but until we obtain more material, especially male specimens, it would be unwise to name it.

### ***Thermonectes basillaris* (Harris)**

*Dytiscus basillaris* HARRIS, 1829, New England Farmer, VIII, p. 1.

*Acilius incisus* Aube var., 1838, C. WATERHOUSE, 1877, Proc. Zoo. Soc., V, pp. 79 and 82.

*Thermonectes basillaris* (Harris), MUTCHLER, 1925, Zoologica, vol. V, no. 20, pp. 225 and 235.

*Thermonectes basillaris* var. *intermedius* CROUCH, 1873, Trans. Am. Ent. Soc. IV, p. 402.

*Acilius laticinctus* LECONTE, 1852, Ann. Lyc. Nat. Hist., N. Y., V, p. 203.

This well-known species which is found throughout North and Central America as well as in the West Indies, breaks up into a number of varieties or races in the different areas of its distribution. The typical form which is found throughout eastern North America is

characterized by being "convex, regularly ovate, dark testaceous, legs and antennae paler, surface scarcely punctulate, black, head in front and a transverse line on the vertex fulvous; thorax with the sides broadly and narrow discoidal transverse line fulvous; elytra with a sub-basal fascia, the external margin and some vague irrorations also fulvous. L .36-.40 inch." G. Crotch. The variety "*intermedius*" has the "Thorax without the median line, elytra with a humeral vitta and a mere trace of the basal fascia; under surface rufotestaceous, Calif. (Horn)." G. Crotch. The variety "*laticinctus*" Leconte is "Similar to the type, but the elytral margin broader and more distinct." G. Crotch. A fourth form has been taken in the Galapagos Islands which I believe is sufficiently divergent and distinct to merit a name. This I will characterize as:

***Thermonectes basillaris galapagoensis* Van Dyke, new subspecies**

Similar in size and general appearance to typical members of *T. basillaris* from eastern North America, having as a rule the complete median transverse testaceous pronotal band and sub-basal elytral transverse band. The males have the pronotum, and elytra smooth and shining likewise but differ in having the rows of elytral discal punctures generally more pronounced, the lateral testaceous margin of the elytra better defined, and the median piceous area much reduced. The females are even more divergent than the males, having, in addition to the color pattern of the males, the pronotum much more coarsely punctate-strigose, and the elytra with the basal area very coarsely strigose-punctured to beyond the middle and the finer punctures extending almost to the apex. In the more northern phases, the elytral punctures are always much finer and practically confined to the basal half of the elytra. In general the most noticeable feature of the race in both sexes, is the broad lighter colored lateral area.

*Holotype* female, allotype male and numerous designated paratypes from a series of thirty-one specimens collected in a brackish pool on Charles Island, October 3, 1905, by F. X. Williams.

This beetle was first recorded from the Galapagos Islands, by Charles Waterhouse, his three specimens having been taken on Charles Island by Commander Cookson. The Harrison Williams Galapagos Expedition of 1923 secured a pair from South Seymour Island in April which were studied by Mutchler. The California Academy Expedition of 1905-1906 secured three specimens of Chatham Island, January, 1906, collected by F. X. Williams, seven from Albemarle Island, March 4-14, 1906, in addition to the type series from Charles Island.

**Eretes sticticus** (Linnaeus)

*Dytiscus sticticus* LINNAEUS, 1767, System. Nat. Ed. 12, p. 666.

*Eretes sticticus* Linnaeus, CASTELNAU, 1832, Ann. Ent. Soc. Fr. I, p. 397.

*Eunectes occidentalis* Erich, C. WATERHOUSE, 1877, Proc. Zoo. Soc., V, pp. 77 and 82.

*Dytiscus sticticus* Linnaeus, SHARP, 1882, Sc. Trans. Roy. Dublin Soc., (2) II, p. 699.

*Eretes sticticus* (Linnaeus), MITCHLER, 1925, Zoologica, V, no. 20, p. 235.

This large water beetle, widely distributed throughout the warmer regions of both the Old World and the New World, like the preceding species, possesses powerful wings and can fly long distances. They both can live in brackish waters, therefore have found very little difficulty in passing from one island to the other. I believe that the latter could readily fly from the mainland. This last remark is in keeping with the statement of Sharp that "this species is found in a greater number of islands than any other of the Dytiscidae."

This species was first reported from the Galapagos Islands, by Charles Waterhouse, his six specimens having been collected on Charles Island by Commander Cookson of U. S. *Petrel*, in pools among lava rocks. The Harrison Williams Galapagos Expedition of 1923, also secured one specimen on Chatham Island, on April 7, from a small pool among lava rocks. The California Academy of Sciences has specimens from Chatham Island, January 1906, and Charles Island, October 3, 1905, collected by F. X. Williams and also specimens from Chatham Island, April 17, 1932, and Indefatigable Island, May 2, 1932, collected by M. Willows, Jr., of the Templeton Crocker Expedition.

Family **GYRINIDAE****Gyrinus galapagoensis** Van Dyke, new species

Elliptical, moderately convex above, somewhat flattened on elytral disc, aeneous with bluish reflections; the undersurface, metasternum, epipleurae, and anal segments piceous. Head with front slightly and bluntly cariniform at middle, a well-impressed fovea near each eye and surface faintly, irregularly strigose, the median strigae longitudinal while those near the eyes are transverse, fronto-clypeal suture deep, the clypeus strigose, eyes prominent. Prothorax with well-defined transverse impression at middle, a large fovea on each side and the area between that and the margin tumid, the row of punctures near anterior margin obliterated at middle and the general surface irregularly strigose, vague at middle but well marked at

sides. Elytra but slightly longer than broad, moderately convex, sides rather evenly arcuate though feebly sinuate at middle, margins fairly wide and feebly reflexed with minute transverse rugae, apices truncate with small oblique carina near outer angle, the disc with lateral striae only impressed, the striae punctures small, metallic green, and moderately close together, those at the sides more conspicuous, first four and a third intervals smooth, next five alutaceous, but the outer one is shining. Under surface smooth and shining. Males, length 4.75 mm., breadth 2.5 mm., females, length 5.5 mm., breadth 3 mm.

"Aedeagus of male as long as the lateral lobes, narrowed at apical fifth, thence parallel sided, half as wide as apical width of a paramere, the tip rounded." H. Leech.

*Holotype* male, allotype female and numerous designated paratypes from a series of twenty-three specimens, collected at an altitude of 1800 feet near **Wreck Bay, Chatham Island**, July 1906, by F. X. Williams.

According to Régimbart's (1902) key, this species belongs near *G. peruvianus* Régimbart, *G. continuus* Régimbart, and *G. aequatoris* Régimbart and is also somewhat suggestive of *G. punctipennis* Régimbart. It is, however, quite distinct from any of these as well as other known species, peculiar features being its reduced convexity, the broad alutaceous sides of the elytra in both sexes, and lateral intervals quite convex, the front of head quite smooth and bifoveate, the pronotal disc rugose and strigose at sides, the elytral striae punctures fine and rather evenly distributed and the elytral apices obliquely truncate and with rounded angles

## Family **HYDROPHILIDAE**

### **Ochthebius batesoni** Blair

*Ochthebius batesoni* BLAIR, 1933, Ann. Mag. Nat. Hist., 10, XI, pp. 473-474.

This small species appears to have been found only by the St. George Expedition of 1924

### **Tropisternus lateralis** (Fabricius)

*Hydrophilus lateralis* FABRICIUS, 1775, Syst. Entom., p. 228.

*Tropisternus lateralis* FABRICIUS, G. R. WATERHOUSE, 1845, Ann. Nat. Hist., XVI, p. 26.

*Tropisternus lateralis* FABRICIUS, C. WATERHOUSE, 1877, Proc. Zoo. Soc., V, pp. 78, 82.

*Tropisternus lateralis* Fabricius, LINELL, 1898, Proc. U. S. Nat. Mus., XXI, no. 1143, p. 255.

*Tropisternus lateralis* Fabricius, MUTCHLER, 1925, Zoologica, V, no. 20, p. 235.

*Tropisternus lateralis* Fabricius, BLAIR, 1933, Ann. Mag. Nat. Hist., ser. 10, XI, pp. 472-473.

This common and widespread North and South American species was collected in the Galapagos Islands by Darwin as well as by all later expeditions. Darwin did not indicate the particular island from which he collected his specimens. The first definite record is by Captain Cookson of H. M. S. *Petrel*, for Charles Island. The California Academy of Sciences Expedition of 1905-1906, secured its specimens mainly from near Villamil, Albemarle Island, March, 1906; and the Templeton Crocker Expedition of 1932, its specimens from Albemarle Island, April 28, 1932, and from Chatham Island, April 18, 1932. It is apparently common and widespread in the Archipelago.

### ***Enochrus waterhousei* Blair**

*Enochrus waterhousei* BLAIR, 1933, Ann. Mag. Nat. Hist., ser. 10, XI, p. 473.

The California Academy of Sciences Expedition apparently did not secure this species. We, however, have two specimens of the type series received through the courtesy of the British Museum.

### ***Enochrus obscurus* (Sharp)**

*Philhydrus obscurus* SHARP, 1882, Biol. Centr.-Amer., Col. I, 2, p. 69.

*Philhydrus* - ?, G. R. WATERHOUSE, 1845, Ann. Nat. Hist., XVI, p. 26.

*Philhydrus* sp., C. WATERHOUSE, 1877, Proc. Zoo. Soc., V, p. 82.

*Philhydrus* species Waterhouse, LINELL, 1898, Proc. U. S. Nat. Mus., XXI, no. 1143, p. 255.

*Philhydrus* species 2, G. R. Waterhouse, MUTCHLER, 1925, Zoologica, V, no. 20, p. 235.

*Enochrus obscurus* Sharp, BLAIR, 1933, Ann. Mag. Nat. Hist., 10, XI, p. 473.

While designating the Galapagos Islands specimens as the above species, Blair (1933) comments in regard to the St. George Expedition material:

“Charles Id., 6 ex.

“The short series agrees better with Sharp’s second and smaller example than with the type, but I cannot find that it differs specifically. From *E. waterhousei* [as corrected by Blair, *galapagoensis* printed in error] it differs in having the prosternum simply convex instead of medially carinate and the median elevation of the mesosternum low and obtuse, not elevated into a vertical plate.

"Although C. Waterhouse lists this species under 'Islands not specified,' Darwin's original specimen bears a label 'Charles Id.,' with the no. 3364 on the reverse side."

The material in the California Academy of Sciences collection is from Charles Island, October 3, 1905, and from near Wreck Bay, at an altitude of 1800 feet, Chatham Island, July, 1906, all collected by F. X. Williams. Two of the latter specimens were carefully checked with the type of *E. obscurus* Sharp, by Blair.

### **Galapagodacnum darwini** Blair

*Coelostoma darwini* BLAIR, 1933, Ann. Mag. Nat. Hist., 10, XI, pp. 474-475.

*Galapagodacnum darwini* (Blair), D'ORCHYMONT, 1937, Am. Mag. Nat. Hist., 20, p. 134.

The California Academy of Sciences possesses specimens from Brattle Island, October 30, 1905; Tower Island, September 14, 1906; and Abingdon Island, September 18, 1906; all collected by F. X. Williams. Most of these were taken from rotting and putrid cactus as is generally the case with these beetles.

### Family **STAPHYLINIDAE**

#### **Bledius aequatorialis** Mutchler

*Bledius aequatorialis* MUTCHLER, 1925, Zoologica, V, no. 20, pp. 225-226, 235, text fig. 43.

The two specimens from which Mutchler described this species were collected by the Williams Galapagos Expedition of 1923 and appear to be the only ones of this genus or species which have ever been taken in the Islands. The genus is widespread throughout the warmer parts of the Americas.

#### **Creophilus villosus** (Gravenhorst)

*Creophilus villosus* (GRAVENHORST), 1802, Coleopt. Microptera Brunsvicensia, p. 160.

*Creophilus* sp., G. R. WATERHOUSE, 1845, Ann. Nat. Hist., XVI, p. 24.

*Creophilus villosus* (Gravenhorst), C. WATERHOUSE, 1877, Proc. Zoo. Soc., V, p. 82.

*Creophilus villosus* (Gravenhorst), LINEA, 1898, Proc. U. S. Nat. Mu., XXI, no. 1143, p. 255.

*Creophilus villosus* (Gravenhorst), MUTCHLER, 1925, Zoologica, V, no. 20, p. 235.



This species which is widely distributed throughout the Americas, was first reported from the Galapagos Islands as from Chatham Island. The California Academy of Sciences has specimens collected at Villamil, Albemarle Island, April 24, 1906, and August 22, 1906, by F. X. Williams.

#### UNIDENTIFIED STAPHYLINIDAE

There are specimens of a number of genera of Staphylinidae which the California Academy of Sciences secured from various islands such as James, Abingdon, and Albemarle, but they cannot be determined until we know more about the staphalinid fauna of western South America.

#### Family **HISTERIDAE**

##### Subfamily DENDROPHILINAE

#### **Carcinops galapagoensis** Van Dyke, new species

Oblong, oval, moderately convex, black, shining; antennae, palpi, and legs rufopiceous. Head feebly convex, uniformly discretely punctured, the lateral groove complete and well impressed. Prothorax almost twice as wide as long, base feebly arcuate, apex strongly emarginate, sides almost straight and slightly convergent to anterior two-thirds, thence distinctly arcuate and convergent to prominent front angles, the disc finely, discretely punctured, the sides much more coarsely and in general with punctures more widely spaced, the side margin complete and well marked, the front margin fine, the base without margin but with a small fovea in front of the scutellum. Elytra about as broad as long, the striae sharply impressed and finely punctured, the sutural or sixth not reaching base, the fifth represented by punctures near base, the dorsal striae 1-4 complete, the internal subhumeral more or less interrupted towards base, the external subhumeral only reaching three-fourths way towards base, and the marginal striae complete; the intervals flat and very finely sparsely punctured, a deep impression at the inner side of the humeral umbone. Propygidium coarsely, rather sparsely punctured, pygidium finely punctured. Prosternum finely punctured, the lateral grooves deep and somewhat sinuous, the apex fully margined; the metasternum, pleural plates, and abdominal segments rather coarsely irregularly punctured, the marginal mesosternal stria short but well marked and united posteriorly with the bifid metasternal stria which continues posteriorly almost to the hind margin of meta-episternum. The first abdominal sclerite marked laterally with a deep stria extending posteriorly from the hind coxal cavity. Anterior

tibiae broadly dilated in front with two prominent teeth on the outer margin in front and the outer margin finely surulate posteriorly. Middle tibiae somewhat arcuate, moderately dilated and with a prominent spine at the middle of its outer margin. Length 2.5 mm., breadth 1.75 mm.

*Holotype* and several paratypes from a series of ten specimens collected on Abingdon Island, September 18-23, 1906, by F. X. Williams. Three other specimens from Tower Island, September 14-16, 1906, and four specimens from Indefatigable Island, July 20-24, 1906, likewise collected by F. X. Williams, have been placed with the above as they agree in all regards.

This species seems to belong in the complex with the North American *Carcinops opuntiae* Leconte which differs in having the punctuation of the sides of the pronotum very much coarser, the elytral striae coarser, the sutural and fifth striae reaching the base but only as a series of punctures, the internal subhumeral complete and the external subhumeral only represented by a puncture, the striae as a whole less complete posteriorly, and the middle tibiae almost straight.

### ***Carcinops tenellus* (Erichson)**

*Paramalus tenellus* ERICHSON, 1834, in King, Jahrb. Ins., 1, p. 170.

*Carcinops tenellus* ERICHSON, MARSEUL, 1855, Mon., p. 94, pl. 8, no. 22, fig. 7.

*Hister corticalis* LECOMTE, 1851, Ann. Lyc. Nat. Hist., N. Y., V, p. 163.

The California Academy of Sciences has seventy-two specimens collected on James Island, December, 1905, S. Albemarle, August 5-9, 1906, by F. X. Williams, which I cannot separate from specimens of *C. tenellus* from the western part of the United States. Outside of the United States, Colombia and Venezuela are listed as furnishing specimens. No doubt the semiarid coastal regions of western South America will in time be found to harbor this species.

### Subfamily SAPRININAE

### ***Saprinus batesoni* Blair**

*Saprinus batesoni* BLAIR, 1933, Ann. Mag. Nat. Hist., ser. 10, vol. XI, pp. 475-476.

The writer has not studied specimens of this species.

### ***Saprinus modestior* Marseul**

*Saprinus modestior* MARSEUL, 1845, Mon., p. 493, t. 19, f. 110.

The California Academy secured no specimens of *Saprinus batesoni* Blair, but it did get a number of specimens of a species of *Saprinus* which apparently agree with Blair's remarks concerning *Saprinus modestior* as well as Marseul's description.

The California Academy material consists of seven specimens collected on Abingdon Island, November 18–23, 1906, by F. X. Williams.

### Family **LYCIDAE**

#### **Calocladon testaceum** Gorham

*Calocladon testaceum* GORHAM, 1881, Biol. Central-Amer., Col. III, 2, p. 28, pl. II, fig. 20.

*Calocladon testaceum* Gorham, BLAIR, 1933, Ann. Mag. Nat. Hist., ser. 10, vol. XI, p. 476.

A single example recorded by Blair, as taken by Bateson of the St. George Expedition, 1924, on Chatham Island. This is a Central American (Nicaragua) species. I am inclined to believe that the specimen was really collected on the mainland and carried to the islands where it was later mixed with island specimens.

### Family **CANTHARIDAE**

#### **Chauliognathus sulphureus** C. Waterhouse

*Chauliognathus sulphureus* C. WATERHOUSE, 1878, Trans. Ent. Soc. London, p. 331.

*Chauliognathus sulphureus* C. Waterhouse, GORHAM, 1881, Biol. Centr.-Amer. Col. III, 2, p. 73.

*Chauliognathus sulphureus* C. Waterhouse, CHAMPION, 1914, Ent. Soc. London, p. 154, t. 7, f. 29 et 27a.

*Chauliognathus sulphureus* C. Waterhouse, BLAIR, 1933, Ann. Mag. Nat. Hist., ser. 10, vol. XI, p. 476.

According to Dr. Blair, one example was taken on Chatham Island. This species, like the preceding, is a Central and South American species and was no doubt listed from Chatham Island as the result of an error.

### Family **MELYRIDAE**

#### **Ablechrus flavipes** C. Waterhouse

*Ablechrus darwinii* C. WATERHOUSE, 1877, Proc. Zoo. Soc., p. 81.

*Ablechrus flavipes* C. WATERHOUSE, 1877, Proc. Zoo. Soc., p. 79.

*Ablechrus flavipes* C. Waterhouse, MUTCHLER, 1925, Zoologica, V, no. 20, p. 235.

This species was listed by C. Waterhouse as from James Island

(C. Darwin). In the California Academy of Sciences collection there is a much injured melyrid from Chatham Island, April 15, 1932, collected by the Templeton Crocker Expedition of 1932. It does not seem to fit the above.

### Family **CLERIDAE**

But two species of this family have so far been reported from the Islands, one a typical member of the family, and the other the well known, now cosmopolitan *Necrobia rufipes* De Geer.

#### ***Pelonium longfieldae* Blair**

Plate VI, figure 2

*Pelonium longfieldae* BLAIR, 1928, Ann. Mag. Nat. Hist., ser 10, I, pp 677-678.

The California Academy of Sciences possesses specimens from the following localities: Charles Island, February 1906, 2 specimens; Albemarle Island, April 28, 1932, February 10-17, 1906, 2 specimens; Chatham Island, November 1905, one specimen; and James Island, December 1905, one specimen.

#### ***Necrobia rufipes* De Geer**

*Clerus rufipes* DE GEER, 1775, Mem., V, p. 165, pl. XV, f. 4.

*Corynetes rufipes* auct., G. R. WATERHOUSE, 1845, Ann. Nat. Hist., XVI, p. 26.

*Corynetes rufipes* Fabricius, C. WATERHOUSE, 1877, Proc. Zoo. Soc., p. 81.

*Corynetes rufipes* De Geer, LINELL, 1898, Proc. U. S. Nat. Mus., XXI, no 1143, p. 257.

*Necrobia rufipes* (De Geer), MITCHLER, 1925, Zoologica, vol. V, no 20, p. 235.

This common scavenger beetle is now widely distributed throughout the Galapagos Islands as in most other parts of the world. The fact that the Pacific whaling fleet visited these islands for tortoises and ballast, for many years, perhaps accounts for some of the introduction. The schooner *Academy*, the vessel which transported the California Academy of Sciences Expedition, as the result of bringing home large numbers of dead and only partly cleaned tortoises, was very badly infested with this beetle as well as by its companion scavenger, *Dermestes vulpinus* Fabricius.

### Family **OEDEMERIDAE**

This family which has representatives on most islands in tropical seas is credited with having four species of two genera restricted to

the Galapagos Islands. One more will be added in this paper. Many of these breed in the driftwood found along the seashore; they also are attracted to lights.

### ***Oxacis galapagoensis* Linell**

*Oxacis galapagoensis* LINELL, 1898, Proc. U. S. Nat. Mus., XXI, no. 1143, pp. 266-267.

*Oxacis galapagoensis* Linell, MUTHLER, 1925, Zoologica, V, no. 20, p. 235.

*Oxacis galapagoensis* Linell, BLAIR, 1928, Ann. Mag. Nat. Hist., ser. 10, 1, p. 673.

Blair (1928) records twenty-one specimens as taken by the St. George Expedition of 1924, on James Island, and comments as follows:

"The species is compared by its describer with the N. American *Alloxis dorsalis* Melsheimer, but is much more nearly related to *O. litoralis*, Champion, from Guatemala and Panama, if indeed, it is really distinct from that species. The punctures of the thorax are relatively large and coarse, very much coarser than those of the elytra, the pubescence is consequently scanty and is directed mainly backwards. In *A. dorsalis* the thoracic puncturation is very fine, scarcely coarser than that of the elytra, and the pubescence denser and directed forwards. From *O. litoralis*, which in sculpture is identical, it differs in its slightly broader thorax and in the outer dark area of the elytra being more extensive, frequently uniting with the small scutellar patch and leaving only a narrow sutural band testaceous."

The California Academy of Sciences possesses sixty-five specimens of this species, all collected by F. X. Williams and from the following localities: Albemarle Island, 24 specimens from February to April 1906; 7 specimens Villamil, Albemarle; 24 specimens from Charles Island, October 3, 1905; and one from Hood Island, January, 1906.

### ***Oxacis pilosa* Champion**

*Oxacis pilosa* CHAMPION, 1890, Biol. Centr.-Amer., Col. IV, 2, p. 156, pl. VII, fig. 15.

*Oxacis pilosa* Champion, BLAIR, 1928, Ann. Mag. Nat. Hist., ser. 10, 1, p. 673.

The St. George Expedition of 1924, is the only expedition which has taken the above-named species on the Galapagos Islands. Dr. Blair (1928) who studied the material collected by this expedition, states:

"James Is., 1 ex. (Type-locality, Guatemala).

"Differs from the last species in its more uniform brownish coloration, long, rather shaggy pubescence, which, however, is similarly inclined on the thorax, distinct elytral costae, and in the much greater

distance separating the eyes on the under side of the head. In the present species this distance is about twice the width of the mentum. The tip of the right mandible is concealed; on the left mandible some distance from the apex there is a slight tooth beneath."

### ***Alloxaxis seymourensis* Mutchler**

*Alloxaxis seymourensis* MUTCHLER, 1925, *Zoologica*, V, no. 20, pp. 226-227.

This species is unknown to the writer.

### ***Alloxaxis collenettei* Blair**

*Alloxaxis collenettei* BLAIR, 1928, *Anns. Mag. Nat. Hist.*, ser. 10, 1, pp. 673-674.

The California Academy of Sciences has twenty-four specimens, collected by F. X. Williams; seven from South Seymour Island, in November 1905; three from Villamil, Albemarle Island, on April 1, 1906; and two from Charles Island on October 3, 1905. The Seymour Island specimens are typical *A. collenetti*, not *A. seymourensis* as might be expected.

### ***Alloxaxis hoodi* Van Dyke, new species**

Small, narrow, uniformly brown above except for very sutural and lateral margins which are somewhat testaceous; uniformly clothed with very short, fine, and well-spaced decumbent pubescent pile, hardly concealing the integument beneath. Head shallowly, densely punctured as usual, and finely and sparsely pubescent; eyes large, prominent, coarsely granular, and widely separated above; antennae extending barely beyond middle of elytra, second segment short, barely more than one-third length of third, the following long and cylindrical, the last feebly constricted at middle, right mandible feebly notched near apex. Prothorax barely longer than broad, widest in front, sides moderately arcuate forward, much narrowed and feebly sinuate in basal half; disc flattened, a broad yet feeble transverse impression in front of middle and a narrow linear transverse impression just in front of basal margin; the surface alutaceous and obscurely punctured. Elytra two and two-thirds longer than broad, almost four times as long as prothorax and slightly broader, with sides parallel, disc somewhat flattened and with sutural and one other costa feebly marked, the inner striae here and there vaguely indicated but the outer entirely obliterated, the general surface minutely alutaceous. Length 6 mm., breadth 1.5 mm.

*Holotype*, a unique collected on **Hood Island**, April 20, 1932, by M. Willows, Jr., of the Templeton Crocker Expedition of 1932.

This small species somewhat resembles the preceding species but is much smaller, of a more uniform brown color, flatter, with the elytral costae less defined, and the pile very much shorter and finer so as to hardly conceal the integument at all.

### Family **MORDELLIDAE**

The species mentioned below is the first of the family to be listed from the Galapagos Islands.

#### **Mordellistena galapagoensis** Van Dyke, new species

Rather small, piceous; the antennae and front and middle legs to a great extent rufous; the elytra rufo-piceous; the body clothed with closely appressed fulvous pile, that of the elytra somewhat more brilliant or golden yellow than elsewhere and forming a definite color pattern as follows: a narrow sutural vitta, an irregular and elongate triangular patch extending backwards and inwards from the humeri, overlying the rufous area; and an irregular broad patch extending laterally from the base almost to apex, with an oblique portion reaching the apex of the triangular patch and extending somewhat beyond but not quite reaching the sutural vitta; as well as a small apical patch the darker portions being a broad triangular basal area on either side of the scutellum which extends back as a narrow streak on either side of the sutural vitta, widening a bit at middle and greatly expanding at apical third; and two small streaks, an oblique one pointing towards humeri and separating the golden triangular patch from lateral portion and a smaller one at margin on the outer side of this. Head smooth and shining behind, very finely punctured and dull in front. Prothorax slightly broader than long and very finely, obscurely punctured. Elytra somewhat more than twice as long as broad, rather closely and regularly punctured. Hind tibiae with four oblique ridges on outer face near apex, the first tarsal segment with three oblique ridges and the second with two. Length 2.5 mm., breadth 1 mm.

*Holotype*, collected on **Tower Island**, March 25, 1935, by the Templeton Crocker Expedition of 1935.

The California Academy of Sciences Expedition of 1905-1906, collected three specimens on Albemarle Island, April 24-27, 1906.

F. X. Williams in his notes for January 9, 1906, on James Island, remarks: "Mordellids not rare on (*Erigeron*?) flowers, 2000 feet."

Evidently Mr. Williams was too busy with other duties at the time to permit him to give time to collecting specimens. I could not find specimens in his material from James Island.

Family **MELOIDAE**

**Cissites maculata** Swederus

*Cissites maculata* SWEDERUS, 1787, Vetensk Acad nya Handl., p. 199, pl. VIII, fig. 8.

*Cissites maculata* SWEDERUS, MUTCHLER, 1938, Am. Mus. Novitates, no. 981, p. 4.

Mutchler (1938) mentions "One specimen Indefatigable Island, flying within 'Ecological Zone A' at 7:30 P. M., Dr. Wolfgang von Hagen.

"This specimen does not agree in all details with the description of *maculata*. The antennae are piceous at the base, becoming paler and more reddish apically, the apical segment being a pale red. Each elytron has the basal mark as in *maculata* but the two median and two subapical spots are replaced by somewhat broad, more or less jagged-edged bands. Otherwise this specimen is like those of other *C. maculata* in the American Museum Collection."

In confirmation of the above note, I will state that Dr. F. X. Williams of the California Academy of Sciences Expedition, states that he took from March 4-14, 1906, the pseudopupa of what is probably this species, from the nests of the carpenter bee, *Xylocopa*. He also states that on February 17, 1906, he found a *Xylocopa* larva in a cell on an old limb, on Chatham Island, being devoured by a parasitic larva, presumably that of *Cissites maculata* Swederus. *Cissites maculata* is a very variable species both as to size and color pattern as shown by specimens in the California Academy of Sciences collection from the Canal Zone and from South America.

Family **ELATERIDAE**

**Conoderus galapagoensis** Van Dyke, new species

Plate VI, figure 4

Rather small, rufocastaneous. antennae, legs, scutellum, and generally the hind angles of prothorax testaceous; the disc of pronotum usually somewhat piceous and the elytra with a triangular scutellar patch and a sutural patch one-third the distance from the apex piceous, the latter generally connected with the scutellar patch by a line along the suture, the mesosternal area also more or less piceous. Head convex,



densely, somewhat coarsely punctured and alutaceous, a feeble longitudinal impression at middle, and with the clypeal margin arcuate; the antennae extending about two segments beyond hind angles of prothorax, the first segment robust, the second small but little longer than broad, the third about one-third longer than second, the third to tenth elongate, feebly serrate and gradually shorter and narrower toward apex, the eleventh elongate with parallel sides. Prothorax somewhat longer than broad, anterior margin feebly bisinuate, dilated in front of hind angles and with sides then gradually converging forwards; the disc convex, feebly flattened at center, densely and somewhat coarsely punctured and alutaceous, the hind angles broadly triangular, directed backwards and with the lateral carina sharply defined and diverging forwards from the side margin, the basal carina lacking. Scutellum convex and finely punctured. Elytra almost twice as long as wide, somewhat flattened on disc, the striae deeply impressed and finely and closely punctured, the intervals flattened apically, more or less convex towards base and finely rugose, the apex conjointly rounded. Beneath rather coarsely and discretely punctured in front, very finely over abdomen. The fourth tarsal segment distinctly lamellate, the lamellae broader than segment and easily seen from above. Length 8 mm., breadth 2.5 mm.

*Holotype*, collected on **Chatham Island**, January 1906, by F. X. Williams. Numerous paratypes have been designed from a series of thirty-seven specimens from the following localities: Chatham Island, February, 1906, Charles Island, May 15, 1906, and Albemarle Island, March 14-24, 1906.

This species superficially resembles *C. varians* (Steinheil) in color-pattern but it is in general broader, more flattened, more coarsely punctured, the third antennal segment proportionately longer, and presents a greasy red appearance. This species is also variable in its color-pattern like its relatives. One paratype is immaculate, the others all have the basal scutellar maculation and posterior cross-like markings quite evident.

### Tribe **Physorhini**

In the tribe Physorhini, there are two genera which have representatives in the Galapagos Islands: *Physorhinus* Eschscholtz and *Anchastus* Leconte. The former is confined to the New World and is characterized by Champion (1894-97) in the *Biologia Centrali-Americana* as having "the posterior coxal plate enormously developed, the subtriangular median portion being nearly or quite as wide as the

first ventral segment. The sutures between the posternum and propleurae are widely separated for the greater part of their length, rather abruptly converging behind, and channeled in front. The middle coxae are deeply excavated externally for the reception of the base of the middle femora, the upper portion forming a broad plate. The third joint of the antennae is very short. The third joint of the tarsi is strongly lamellate, the fourth joint small. The curious pallid coloration of the whole or part of the head is common to all of the species."

The fundamental characters are to me, the greatly dilated posterior coxal plates, the widely separated sutures between the prosternum and propleurae, and the channelling in front between them and the strongly lamellate third tarsal segment. The pallid head, so characteristic of both North and South American species, is not found in the species from the Galapagos Islands. Including *Anchastus quirsfeldi* Mutchler, which is a true *Physorhinus*, not an *Anchastus*, I have seen seven species of this genus from the Galapagos Islands. They are as follows:

### ***Physorhinus quirsfeldi* (Mutchler)**

*Anchastus quirsfeldi* MUTCHLER, 1938, Amer. Mus. Novitates, no. 981, p. 4.

Through the kindness of the American Museum of Natural History and Dr. Mont Cazier, I have a paratype of this species before me. As stated above, I find that it is a *Physorhinus*, having the posterior coxal plates greatly developed, the sutures between the prosternum and propleurae widely separated and the area between channelled in front, and the third segment of the tarsi strongly lamellate. These are all characters of a typical *Physorhinus*. It, however, lacks the pallid yellow color of the head which is so evident in the mainland species of the genus, but has the head of the same color as the after-body as is the case with most of the island species. I am inclined to believe that this latter character is of less value than what I consider as the fundamental characters

### ***Physorhinus dichroa* Van Dyke, new species**

Of fair size, robust, piceous, antennae and legs rufous, sparsely clothed above with fine and somewhat fulvous pile. Head convex, the front coarsely punctured behind, more densely and finely in front, the clypeus feebly arcuate in front, almost transverse and with a narrow, feebly reflexed margin; the antennae stout, extending behind hind angles of prothorax, the basal segment robust, the second and third small, the first transverse, the second slightly longer than broad, fourth to tenth strongly serrate and one and a half to twice as long as broad,

the eleventh elongate. Prothorax somewhat broader than long, apex feebly emarginate, sides almost parallel behind, arcuate and converging forwards, hind angles prominent, pointed backwards, bicarinate, the outer carina fine and close to margin, the inner shorter and divergent, the disc convex, with a shallow median canaliculation towards base, coarsely and densely punctured and feebly alutaceous. Elytra two and a half times as long as broad. Convex, finely striate-punctured, the striae well defined basally, somewhat vague apically, the intervals flat and finely, irregularly punctured, each puncture with a fine hair arising from it. Beneath with the propleurae moderately punctured in front, smooth, shining and feebly punctured behind, mesopleurae and basal abdominal sclerites coarsely and densely punctured, the apical sclerites more finely punctured, the inclined fulvous pile quite evident, especially on abdomen; the sutures between prosternum widely divergent in front, convergent behind but feebly grooved between, the posterior coxal plates well developed, almost as long as the abdominal sclerites are broad; the tarsi with the third segment strongly lamellate, and the fourth segment small as usual. Length 13 mm., breadth 4 mm. The wings are fully developed, probably functional.

This species is characterized by its size, red legs, small second and third antennal segments, broad prothorax and feebly grooved area between the prosternal and propleural sutures.

*Holotype*, presumably a male, collected on **James Island**, in December 1905, by F. X. Williams. Two paratypes, a male and female were collected at the same time and place.

### ***Physorhinus ruficeps* Van Dyke, new species**

Of moderate size, robust, piceous; the head, front, and sides of pronotum, antennae, and legs rufous, sparsely clothed with fine, fulvous pile. Head coarsely, densely and somewhat cribrately punctured, the clypeus arcuate in front and with a well-defined narrow and feebly reflexed margin; the antennae robust extending one or two segments beyond hind margin of prothorax, the basal segment stout, second very small and transverse, third feebly triangular and about twice as long as second; fourth to tenth elongate, feebly serrate and gradually longer and narrower towards apex; eleventh segment elongate. Prothorax slightly broader than long, apex feebly emarginate, sides arcuate and convergent forwards, the prothorax thus cuneate in shape, hind angles rather short but well marked and pointed backwards, bicarinate, the outer carina the longer, close to and parallel to the outer margin, the inner short and divergent, the disc convex, the median

longitudinal impression very feebly indicated towards base, densely and coarsely punctured, the punctures somewhat approximate at sides. Elytra more than twice as long as wide, broad, the striae well impressed except apically, finely and closely punctured, the intervals feebly convex basally, irregularly biserially punctured, each puncture with a fine hair arising from it. Beneath, the propleurae finely and shallowly punctured, the mesopleurae and abdomen more coarsely and densely so and the last ventral segment very finely and densely punctured, the fulvous pile very evident; the sutures between prosternum and propleurae widely divergent in front, convergent behind and the area between markedly sulcate. The posterior coxal plates well developed, almost as long as the abdominal sclerites are broad, the tarsi with the third segment strongly lamellate and the fourth segment small. Length 10 mm, breadth 4 mm.

*Holotype*, supposedly a male, a unique from **Villamil, Albemarle Island**, collected April 24, 1906, by F. X. Williams.

This species is easily separated by its rufous head and sides of pronotum, the small second antennal segment, much larger third segment and the elongate and narrowed segments from the fourth to tenth. The euneate prothorax is also characteristic of most of the species in the genus.

### ***Physorhinus hoodi* Van Dyke, new species**

Medium sized, robust, brown; the clypeal region of head, antennae, and legs rufous; sparsely clothed with short fulvous pile. Head convex, rather coarsely and densely punctured, the clypeus arcuate in front, the margin narrow and feebly reflexed, the antennae extending about one segment beyond hind angles of prothorax, the basal segment robust, the second small and transverse, the third segment somewhat larger, the fourth to tenth segments broader, elongate and feebly serrate. Prothorax as long as broad, apex feebly emarginate, sides arcuate, very gradually convergent forwards, hind angles prominent, projecting backwards, bicarinate, the outer carina fine and close to lateral margin, the inner shorter and divergent. The disc convex, with median longitudinal impression very faint, finely and discretely punctured, more coarsely and densely punctured at sides. Elytra two and two-thirds as long as broad, the striae sharply defined except at sides and apex and finely and closely punctured, the intervals flat behind, feebly convex towards base and finely rugose, and with an irregular double row of minute punctures from which arise the short fulvous hairs. Beneath with the propleurae rather coarsely and densely punctured, the abdo-

men more finely and sparsely punctured; the sutures between prosternum and propleurae widely divergent in front and the area between them sulcate, the posterior coxal plates greatly developed, fully as long as the ventral segments are broad; the tarsi with the third segment lamellate and the fourth minute. Length 10 mm., breadth 3 mm.

*Holotype*, a unique collected on **Hood Island**, in February, 1906, by F. X. Williams.

This species may be recognized by having the head anteriorly distinctly rufous, the prothorax less cuneate, the body in general quite robust and the elytral intervals somewhat convex basally and distinctly rugose. The hind coxal plates are also more greatly developed than they are in other species.

### ***Physorhinus blairi* Van Dyke, new species**

Somewhat small, entire upper surface dark brown, antennae and legs castaneous and sparsely clothed with fulvous pile. Head convex, densely and eribrately punctured; the clypeus arcuate in front and the margin feebly reflexed; the antennae rather delicate, extending several segments beyond the base of prothorax in the male type and one segment beyond the hind angles of the prothorax in the female, the basal segment robust, the second segment small and transverse, the third segment slightly longer in the female and about twice as long in the male, the fourth to tenth segments several times as long as broad, feebly serrate and also gradually narrowed towards apex though more robust in males than females, and the eleventh segment elongate. Prothorax as long as broad, somewhat cuneiform, the apex feebly emarginate, sides slightly arcuate and convergent forwards, hind angles prominent, projecting backwards, bicarinate, the outer carina close to the margin, the inner a bit shorter and divergent, the disc convex with the median canaliculation faintly indicated, and finely and rather densely yet discretely punctured above but approximate at the sides. Elytra about two and one-half times as long as broad, convex, striae finely and closely punctured but more or less obliterated apically and at the sides, the intervals flat, very finely and irregularly punctured with a fine hair arising from each puncture. Beneath densely punctured in front, coarsely over the prosternum, finely on the propleurae and finely and discretely over the abdomen except the last segment which is densely punctured; the sutures between the prosternum and propleurae well separated in front but the area between feebly channeled; the posterior coxal plates greatly developed as usual in the

genus, and the tarsi with the third segment lamellate and the fourth very small. Length 10 mm., breadth 3 mm.

*Holotype* male and allotype female, collected on **James Island**, February 20-22, 1925, by G. Bateson. The male type will be returned to the British Museum of Natural History.

This species is one of the smaller species of the genus, averaging 10 mm. in length and is more or less uniformly of a dark brown color above, with densely punctured head, elytra with the striae to a great extent obliterated posteriorly and the third antennal segment longer in the male than in the female. The lack of a pronounced channel between the prosternal and propleural sutures suggests an approach towards *Anchastus* but the greatly developed hind coxal plates indicates that it is a *Physorhinus*.

#### **Physorhinus batesoni** Van Dyke, new species

This small species has all of the essential characters of the genus: the dilated hind coxal plates, the divergent sutures between the prosternum and propleurae with the area between grooved, and the lamellate third tarsal segment and small fourth segment which it shares with *Anchastus*. It is closely related to *P. blairi* having the head densely punctured though not as eribrately, the second and third antennal segments both small and the elytral striae only well defined in the basal two-thirds. It is, however, smaller, 8 mm. long by 2.5 mm. broad, rufopiceous above and rufous beneath, the scutellum fulvous, with the pronotum moderately but discretely punctured on the disc rather coarsely at the sides in front and more finely towards the base and the median longitudinal impression lacking.

*Holotype*, a unique, collected on **Albemarle Island**, in 1925, by G. Bateson. It will be returned to the British Museum of Natural History from which institution it was borrowed.

#### **Physorhinus chathamii** Van Dyke, new species

This species is of the same size as *P. blairi*, and of the same general brown color except that the scutellum and front of head are somewhat rufous. It differs by having the area between the prosternal and propleural sutures distinctly channeled, the punctuation of head and pronotum less coarse, the hind angles of prothorax more acute and the elytra with the striae sharply impressed, finely and closely punctured, and not entirely obliterated apically, and the striae quite definitely rugose towards the base. It also has the second and third antennal

segments both small, the third a bit the larger, and the hind coxal plates very large.

*Holotype*, a unique, collected on **Chatham Island**, January, 1906, by F. X. Williams.

#### KEY TO SPECIES OF GALAPAGOS ISLANDS *PHYSORRHINUS* ESCHSCHOLTZ

1. Second antennal segment alone small, the third at least one-half length of fourth; larger species, 12 mm. or more in length ..... 2
- Second and third antennal segments both small except in female of *P. blairi* where it is about one-half length of fourth..... 3
2. Black with antennae and legs alone rufous; third antennal segment fully one-half length of fourth, Indefatigable Island.....  
.....*P. quirsfeldi* (Mutchler)
- Dark brown with antennae, legs, head, anterior margin of pronotum and scutellum rufous; third antennal segment fully one-half length of fourth; Villamil, Albemarle Island ..... *P. ruficeps*, new species
3. Larger species, over 12 mm. in length, both second and third antennal segments small, black with antennae and legs rufous, outer segments of antennae strongly serrate; James Island. .... *P. dichroa*, new species
- Smaller species, 10 mm. or less in length ..... 4
4. Antennae, legs, front of head and scutellum rufous, body dark brown; Hood Island..... *P. hoodi*, new species
- Body above unicolorous. .... 5
- 5 Body above rufocastaneous, beneath castaneous, 8 mm. in length. Albemarle Island..... *P. batesoni*, new species
- Body above dark brown, beneath somewhat lighter; 10 mm. in length 6
- 6 Antennal segments two and three both small, area between prosternal and propleural sutures definitely channeled in front Chatham Island .  
..... *P. chatham* Van Dyke
- Antennal segment two small and three at least twice its length in male, two and three both small in female, area between prosternal and propleurae feebly grooved or flattened in front; James Island.....  
..... *P. blairi*, new species

#### **Anchastus** Leconte

In the *Biologia Centrali-Americana*, Champion states that "The species here referred to *Anchastus* agree in the following particulars: Front separated from the anterior margin of the head by a rounded or subangular ridge, which is sometimes obliterated in the middle; the sutures between the prosternum and propleurae narrowly separated, channeled or not in front; posterior coxal plates abruptly and sub-quadrangularly widened inwards, in some species acutely triangularly

dilated near the middle; third tarsal joint rather broadly lamellate beneath, the following small."

*Anchastus galapagoensis* (Waterhouse) is listed as from the Galapagos Islands but under the generic name *Physorhinus*. Champion in the Biologia Centrali-Americana states that the supposed type in the British Museum is a true *Anchastus*. Candeze describes *A. galapagoensis* as a *Physorhinus*. Whether a Candeze specimen ever found its way to the British Museum is a question. It is not there now as I carefully looked for it. I am following Junk's Coleopterorum Catalogue in listing the species of both Waterhouse and Candeze.

### ***Anchastus galapagoensis* (Waterhouse)**

*Physorhinus galapagoensis* WATERHOUSE, 1845, Ann. Nat. Hist., XVI, p. 25

*Physorhinus galapagoensis* Waterhouse, CANDEZE, 1859, Mon. II, p. 394.

*Anchastus galapagoensis* Waterhouse, CHAMPION, 1895, Biol. Centr.-Amer. Col., III, p. 385.

I have not repeated the supplementary remarks of either Waterhouse or Candeze. It was not stated from what island the Waterhouse type came and no specimens of *Anchastus* that answer to the descriptions given above have been taken since. The following description is of a species that I consider different.

### ***Anchastus williamsi* Van Dyke, new species**

Of moderate size, brown above; the antennae, legs, and underside more or less rufous; the head and pronotum clothed with short, semi-erect fulvous pile; the elytra with similar pile but more closely appressed. Head convex, coarsely and densely punctured, the clypeus feebly angulate in front, the margin distinctly defined and somewhat reflexed; the antennae about reaching the hind prothoracic angles, the first segment robust, the second small and but little longer than broad, the third to tenth elongate, feebly serrate and gradually broader towards apex; eleventh segment fusiform. Prothorax slightly longer than broad, somewhat eumate in shape, the apex feebly emarginate, the sides quite straight, convergent forwards to the slightly rounded front angles, hind angles sharp and prominent, feebly divergent, the single carina well defined and slightly divergent from the carinate side margin; the disc convex, with a faint median longitudinal impression near base, densely punctured, the punctures somewhat coarser at sides as usual. Elytra more than twice as long as wide, the striae fine and well impressed, the striae punctures distinct and close together, the intervals finely rugose. Beneath rather coarsely and



densely punctured in front, the abdomen more finely and sparsely punctured; the prosternal and propleural sutures feebly diverging in front, the area between closed in front and the sulcus feebly indicated; the posterior coxal plates but moderately developed, about one-half as long as the abdominal sclerites are broad; the tarsi with the third segment provided with a moderately prominent lamella and the fourth segment very small as usual. Length 8 mm., breadth 2.5 mm.

*Holotype*, apparently a female, a unique collected on **Indefatigable Island**, January 1906, by F. X. Williams.

This species is a true *Anchastus* as defined by the characteristics of the prosternal sutures and the hind coxal plates and tarsi. This species differs from *Anchastus galapagoensis* Waterhouse as defined in the description by not having the anterior portion of the head pallid and the third antennal segment as long as the fourth not small like the second as stated by both Waterhouse and Candeze for *A. galapagoensis*.

### **Heterocrepidius puberulus** Boheman

*Heterocrepidius puberulus* BOHEMAN, 1858, Fregatten Eugenies Resa, I, p. 66.

The California Academy of Sciences possesses no specimen which fits the description of this species. Apparently it has not been taken since the voyage of the *Eugenie*.

### **Aeolus fuscatus** Steinhil

*Aeolus fuscatus* STEINHIL, 1875, Col. Hefte XIV, p. 125.

*Aeolus fuscatus* Steinhil, MÜTCHLER, 1938, Am. Mus. Novitates, no. 981, pp. 4-5.

The California Academy of Sciences possesses no specimen of this species. Mutchler had two. His comments are as follows: "One specimen from Charles Island and one from Indefatigable Island 'Ecological Zone C.' The latter, collected by Dr. Wolfgang von Hagen, may be the above species, but the identification is more or less doubtful. They are 6-6.5 mm. in length. The thorax and elytra are reddish brown, but the thoracic angles and margins of the elytra are not paler, the hind angles of the thorax are slightly divergent, the carina is somewhat distinct and extends some distance beyond the base of the thorax. The head and pronotum are quite finely and somewhat densely punctate. The pubescence on the head and pronotum is quite sparse, especially on the disk. The striae of the elytra are well marked and the intervals are flat, the pubescence (probably rubbed) is somewhat more sparse on the disk than at the sides and apex in the Charles Island specimen, but in the other it is more uniform. The body beneath is similar in

color to the upper surface; closely punctate and with short sparse pubescence. Legs pubescent and slightly paler.

"Described from one specimen collected at Nare, Colombia. I have been unable to find any record of this species being recognized since 1875 when the original description appeared."

***Grammophorus galapagoensis* Van Dyke, new species**

Short, robust, black; the front of head, hind prothoracic angles, antennae and legs ferruginous and sparsely clothed with gray pile. Head feebly convex, densely and rather coarsely punctured, clypeal margin distinct and arcuate; antennae not reaching hind angles of prothorax, first segment elongate, robust and bowed, the second segment small, but little longer than broad, the third about as long as broad and subcylindrical, the fourth to tenth elongate and serrate and gradually shorter towards apex, the eleventh segment fusiform. Prothorax two-fifths longer than broad, very convex, densely coarsely punctured, with but the faintest impression towards base of the median longitudinal impression, the apex feebly emarginate, the sides straight and parallel behind, rounded and slightly convergent in front, the base transverse at middle, the hind angles prominent, triangular and directed backwards, the carinae well marked. Elytra two-fifths longer than broad, convex, humeral area obliquely rounded, sides feebly arcuate and gradually convergent to apex, the striae well impressed and rather coarsely and closely punctured; intervals flat and finely rugose. Beneath densely and coarsely punctured in front, the abdomen more finely punctured, pubescent, the last abdominal segment densely clothed with fulvous pile. Legs moderately long and delicate. The true wings are much reduced in size and nonfunctional. Length 9 mm., breadth 3 mm.

*Holotype*, supposedly a female, collected on **Duncan Island**, September 17, 1905, by F. X. Williams.

A second specimen of *Grammophorus galapagoensis*, from Indefatigable Island, November 17-19, 1905, F. X. Williams collector, has been found in the Academy duplicates.

This stubby, elliptical-shaped species, because of its size and general appearance can be readily separated from the mainland, fully winged species. It is apparently most closely related to the Chilean *Grammophora minor* Schwarz but lacks the black legs, canaliculate pronotum, and very acute hind prothoracic angles of the latter. While showing marked degenerative modifications as a result of its insular life, *G. galapagoensis* yet retains all of the fundamental generic characteristics.

**Coptostethus williamsi** Mutchler

*Coptostethus williamsi* MUTCHLER, 1925, Zoologica, vol. V, no. 20, pp. 227-228. text fig. 227.

In the collection of the California Academy of Sciences, there is a series of a hundred and nine specimens of this species collected on Abingdon Island, in September 1906, and Bindloe Island, September 16, 1906, by F. X. Williams.

Family **BUPRESTIDAE****Chrysobothris williamsi** Van Dyke, new species

Plate VI, figure 6

Small, moderately convex, smooth and shining, cupreous, the elytra with three transverse bluish green bands placed as follows: on each elytron, a subbasal spot running from near suture to humeral umbone, broad and triangular and in basal depression and not reaching base, suture or lateral margin; a second or submedian band, chevron-like, commencing near the suture, extending backwards to about the middle of the elytron, thence forward toward the humeral umbone; and a third band, placed midway between the submedian band and the apex, rather short and extending from a short carina at the outer side of the suture towards the lateral margin. In addition there is a short longitudinal green line in the apical region, which runs obliquely to the apex. The upper surface is rather densely punctured especially on the pronotum and in the green areas of the elytra. Head with the occiput broad between the eyes and with a fine median longitudinal carina; the front moderately convex above, flattened or feebly concave below and with an irregular transverse carina separating the two areas, rather densely and coarsely punctured, especially beneath the transverse carina, and with short and depressed white pile arising from the punctures; the clypeus broadly, triangularly emarginate in front; the antennae rather short and bronzed, the segments four to ten serrate and of about equal width. The prothorax broader than long, the sides almost straight and parallel, feebly narrowed behind, the disc moderately convex, without median sulcus or callosities and feebly strigose towards base. The elytra about twice as long as wide, with the base of each elytron extending forwards in a triangular manner, with a deep impression to the outer side of the scutellum, a feeble impression at about the middle, the suture carinate apically and a short carina parallel and to the outer side of the sutural and extending from the middle to the apex but diverging in an arcuate manner apically. The front fe-

mora with a prominent tooth, and the tibiae without apical dilatation. Beneath bronzed and shining, the prosternum densely, coarsely punctured, the abdomen rather sparsely punctured at the middle, densely and finely at the sides and finely pubescent, the segments feebly flattened in front, without posterior median sulcus or lateral callosities, the apical segment with a truncate emargination. Length 6 mm., breadth 3 mm.

*Holotype* male, from **Chatham Island**, February, 1906, collected by F. X. Williams from the hat of a companion.

Besides the holotype, three other specimens have been found, two from Tagus Cove, Albemarle Island, March 17, 1906, and one from Duncan Island, December 1-17, 1905, all collected by F. X. Williams.

This species is rather closely related to *Chrysobothris viridimpressa* Laporte and Gory from Colombia. It was compared with a specimen in the British Museum of Natural History and found to differ as follows: the clypeus of *C. williamsi* more deeply incised in front, the front less coarsely punctured, the interocular space as broad as width of eyes, narrower than width in *C. viridimpressa*, the pronotum with punctures more numerous in *C. williamsi*, also the side margin somewhat angulate in front beneath, also uniformly bronzed, whereas there is a shining green area along the entire center and more coarsely punctured surface in general in *C. viridimpressa*. The last ventral in the male also has a shallow longitudinal sulcus and the apex with a semilunar emargination flanked with two sharp teeth. The elytral markings were also slightly different in two species, *C. viridimpressa* having the basal green bar very markedly bilobed posteriorly, the median bar almost transverse and with two small spots, one on either side of the suture in front.

### **Mastogenius galapagoensis** Van Dyke, new species

Small, black, smooth, and shining. Head convex, without median impression, sparsely and rather coarsely punctured, antennae short, reaching but little beyond the middle of prothorax, second segment robust, third segment small, fourth elongate, fifth to eighth slightly serrate, the terminal cuncate prothorax wider than long, widest about middle, sides feebly arcuate, apex feebly emarginate and very narrowly margined, base emarginate and distinctly margined; the disc convex and rather coarsely punctured, the punctures well separated. Elytra about two and one-half times as long as prothorax, somewhat narrower, with sides straight and parallel in basal two thirds, feebly arcuate and convergent to apex; the disc convex, coarsely and deeply

punctured, the punctures well spaced and somewhat larger than on the prothorax, a transverse carina at the base of each elytron and a well marked transverse impression immediately behind and the suture feebly carinate towards base. Pro-, meso-, and metasternum rather coarsely punctured, the abdomen a bit more finely and shallowly punctured; a distinct linear sulcus at the inner margin of the eyes and along the inner margin of the propleurae in which the antennae rest when in repose; and the posterior margin of hind coxal plate sinuate. Length 2 mm., breadth 1 mm.

*Holotype*, a unique male collected on **Gardner Island** near Hood Island, April 22, 1932, by M. Willows, Jr., of the Templeton Crocker Expedition of 1932.

This species is fully as small as our smallest specimens of *Mastogenius subcyanous* (Leconte), more robust and more coarsely and discretely punctured. Our other species: *M. puncticollis* Schaeffer and *M. robustus* Schaeffer are larger, more parallel and more densely punctured. I have not seen either *M. impressipennis* Fall or any of the South American species but do not believe that it could be one of them.

### ***Mastogenius cuneaticollis* Van Dyke, new species**

This species is considerably larger than the preceding, the prothorax is decidedly wider than long, widest slightly behind the apex, thence with sides almost straight and somewhat convergent towards the base, the pronotum rather densely punctured and scabrous, the prosternum densely and coarsely punctured, and the body generally more elongate and parallel than in the preceding and also aeneous and shining. Length of holotype, 2 mm., breadth 1 mm.; of paratype, length 4 mm., and breadth 1.5 mm.

*Holotype*, apparently a female, collected at **Fossil Cove, Indefatigable Island**, December 17-19, 1905, by F. X. Williams. A second specimen which I am placing with the above as a paratype, is considerably larger, otherwise similar, and was collected on James Island, January 5, 1906, by F. X. Williams. This species lacks the well defined sulcus on the propleurae.

### OTHER BUPRESTIDAE

In addition to the three species of Buprestidae mentioned above, there are probably others in the Islands. Dr. F. X. Williams states in his notes that he found buprestids actively running on the trunks of a slender-leaved croton, on April 20, 1905, at Tagus Cove, Albemarle Island. It was a hot day and they were very active. Apparently none

was secured. On Duncan Island, on August 14, 1906, an elytron was found in the stomach of a lizard, also several dead croton twigs seemed to show the work of buprestids.

### Family **DERMESTIDAE**

#### **Dermestes carnivorus** Fabricius

*Dermestes carnivorus* FABRICIUS, 1775, Syst. Ent., p. 55.

*Dermestes carnivorus* Fabricius, LINELL, 1898, Proc. U. S. Nat. Mus., XXI, no. 1143, p. 256.

*Dermestes carnivorus* Fabricius, MITCHLER, 1925, Zoologica, vol. V, no. 20, p. 236.

*Dermestes carnivorus* Fabricius, HINTON, 1945, Monogr. Beetles Assoc. with Stored Products, British Mus. Nat. Hist., vol. I, pp. 285-287.

One specimen of this species was collected on Chatham Island by the Albatross Expedition of 1891, according to Linell. None was taken since until Mr. F. X. Williams, of the California Academy of Sciences Expedition of 1905-1906, secured a second specimen near Cape Rose, South Albemarle Island, on April 25, 1906, on the carcass of a steer. According to Hinton, the species is found in North and South America, Europe, and India, and according to Fauvel (1889), it is indigenous to America.

#### **Dermestes maculatus** De Geer

*Dermestes maculatus* DE GEER, 1774, Mem. Ins., 4, p. 223.

*Dermestes vulpinus* Fabricius, 1781, Spec. Ins., 1, p. 64.

*Dermestes vulpinus* of authors, G. R. WATERHOUSE, 1845, Ann. Nat. Hist., XVI, p. 26.

*Dermestes vulpinus* Fabricius, C. WATERHOUSE, 1877, Proc. Zoo. Soc., p. 81.

*Dermestes vulpinus* Fabricius, LINELL, 1898, Proc. U. S. Nat. Mus., XXI, no. 1143, p. 256.

*Dermestes vulpinus* Fabricius, MITCHLER, 1925, Zoologica, V, no. 20, p. 236.

*Dermestes maculatus* De Geer, LEFEBVRE, 1939, Bull. Ent. Soc. France, 44, p. 192.

*Dermestes maculatus* De Geer, BARBER, 1942, Bull. Brooklyn Ent. Soc. XXXVII, p. 176.

*Dermestes maculatus* De Geer, HINTON, 1945, Monogr. Beetles Assoc. with Stored Products, British Mus. Nat. Hist., vol. I, pp. 261-268.

This species is widely distributed in the Archipelago, to be found on practically all of the islands, especially where cattle have been slaughtered or animals died. The schooner *Academy* which carried the members of the California Academy of Sciences Expedition to and

from the Islands was badly infested with these beetles as the result of carrying a large number of tortoise skeletons on the homeward journey. Charles Darwin was the first to secure specimens from the Islands.

### Family **OSTOMIDAE**

#### ***Temnochila galapagoensis* Mutchler**

*Temnochila galapagoensis* MUTCHLER, 1938, Am. Mus. Novitates, no. 981, pp. 5-7, fig. 4.

Moderate in size and elongate as usual, rufous with more or less of a greenish bronze color above, head and pronotum somewhat dull, obscurely alutaceous and the elytra shining. Head with median impressed longitudinal line in front and somewhat regularly punctured with moderate sized, shallow punctures which are from two to several times their own diameter apart; antennae rufous. Prothorax one-fifth broader than long, apex a broad lobe, front angles slightly projecting forward, sides irregularly arcuate and somewhat sinuous especially at middle and before base and gradually narrowed posteriorly, the base one-fifth narrower than apex, somewhat arcuate and like the sides and anterior angles distinctly margined; disc moderately convex and with punctures quite coarse medially but finer towards sides, and rather regularly and well spaced as on the head. Elytra almost twice as long as wide and about three times as long as prothorax, emarginate at base, with well defined beadlike basal margin, humeral angles prominent and right angled but rounded at apices, sides subparallel and apex rounded as usual; disc with striae poorly defined and with striae punctures hardly distinguishable from those of the interstriae though the latter are often somewhat smaller and both striae and interstitial series are quite regular in serial arrangement and at the individual punctures somewhat close together. Beneath prosternum sparsely and finely punctured in front, distinctly margined posteriorly, the margin laterally connected with the apices of the epimera; metasternum and first ventral segment minutely and sparsely punctured, the remaining ventral segments more coarsely and densely punctured. Length 15-17 mm., breadth 6 mm.

“Male. Sub-mental area with a somewhat large projecting armature. The fifth and sixth abdominal segments broadly impressed, concave. Female. Sub-mental area smooth, abdominal segments convex.” Mutchler.

This somewhat olive green species, I place in Sharp's (1891, p. 393) Group B, in which the prosternum is margined posteriorly and the

margin laterally joins the apices of the epimera. Of the three species included in the group by Sharp, it resembles somewhat both *T. challea* Kirsch, and *T. quadricollis* Reitter, the former the most. In these two, the sides of the prothorax are quite parallel and the anterior or humeral angle of the elytra sharply rectangular, whereas in *T. galapagoensis* the sides of the prothorax arcuately diverge forwards and the anterior angles of the elytra are rounded. In *T. challea* and *T. quadricollis*, the prothorax is also about as long as broad while in *T. galapagoensis* it is much broader than long. The prosternal punctures in the last are also much finer than in *T. challea*. *Temnochila galapagoensis* is also a much less metallic species, the others being brilliantly metallic.

I have before me, twenty specimens of this species: thirteen from James Island, December 22, 1905, four from Albemarle Island, September 30, 1906, all collected by F. X. Williams, and three from Indefatigable Island, one collected in January 1906, by F. X. Williams and a paratype from the American Museum, collected October 20, 1935, by W. Von Hagen.

### **Tenebroides sp. ?**

A single specimen from Villamil, South Albemarle Island, collected August 20, 1906, by F. X. Williams, which bears some resemblance to the North American *Tenebroides semicylindrica* (Horn) is before me. In the absence of more material, I feel that it is unwise to describe this as new.

### Family **NITIDULIDAE**

#### **Stelidota insularis** Van Dyke, new species

Small, elliptical, testaceous, with basal portion of head, disc of pronotum and disc of elytra piceous. Head with occiput very finely, sparsely punctured and distinctly separated from the front by a fine, slightly elevated, transverse interocular line, the front more coarsely punctured and finely and sparsely pubescent, clypeus convex and finely punctured, the clypeus and mouthparts castaneous; eyes prominent, antennae castaneous. Prothorax transverse, almost twice as broad as long, with front margin straight and hind margin feebly sinuate, sides gradually arcuate and divergent backwards from the obtuse front angles to about the middle, then almost straight and parallel to base, the hind angles somewhat acute and projecting backwards to a slight degree, the side margin complete and fine; disc with rather large, well separated and but feebly impressed variolate punctures and sparsely and finely pilose, the sides not explanate. Scutellum broad, transversely



impressed near base and finely punctured. Elytra about one-fourth longer than broad, piceous with a broad and irregular testaceous base, the lateral margin testaceous, large, and somewhat elliptical, transverse macules near the summit of the declivity testaceous, the apical area also somewhat testaceous, elsewhere piceous; striae finely, feebly impressed and each, as also the center of the rather broad, flat intervals, with a row of very small, short somewhat inclined and closely placed setae, those of the intervals somewhat the longer, the general surface smooth and shining. Beneath, the legs and sides of body finely pubescent, the punctuation shallow. Hind tibia in males straight. Length 2.5 mm., breadth 1.5 mm.

*Holotype* and nine paratypes, the holotype and three paratypes collected on **Indefatigable Island**, November 9 and 15, 1905, the others collected on Chatham Island in February 1906, all by F. X. Williams.

This species seems to be distinct from all described species, being perhaps closest to the Central American *Stelidota championi* Sharp. Its distinctive characteristics are its color pattern, type of pronotal sculpturing, sides of prothorax less flattened behind than in *S. championi* and other Central American species, nonexplanate side margins of prothorax and straight hind tibiae in males.

### **Haptonchus luteolus** (Erichson)

*Epuraea luteola* ERICHSON, 1843, in Germar Zeitschr. f. d. Ent., IV, p. 272. The extensive bibliography is not introduced.

Five specimens were found in the collection: four from Banks Bay, Albemarle Island, April 10-17, 1906, and one from Villamil, Albemarle Island, August 20, 1906, all collected by F. X. Williams. Inasmuch as settlements were in the neighborhood, it is probable that this common cosmopolitan species was introduced.

### Family **CUCUJIDAE**

#### **Silvanus tropicalis** Van Dyke, new species

Small, elongate, subparallel, head and prothorax rufotestaceous, rest of body castaneous. Head evenly convex, coarsely cribrately punctured, each puncture with a minute and backwardly inclined seta; eyes coarsely granular and prominent; antennae of moderate length, reaching about middle of prothorax and suddenly clavate, segments four to seven slightly longer than wide and of about equal length, eighth triangular and feebly transverse; segments of club transverse, the tenth

barely twice as wide as long; all segments well separated. Prothorax about one-fourth longer than broad, apex arcuate, base constricted and lobed, apical angles in the form of small lobes transversely projecting and with margins minutely serrate; disc moderately convex, impressed towards base, and coarsely, cribrately punctured and with minute, inclined setae as on head. Elytra about twice as long as wide with rounded humeri, sides subparallel and evenly rounded to apex; disc moderately convex, with striae regular, hardly impressed but with coarse, closely placed punctures, intervals flat, each with a row of minute, inclined setae. Beneath coarsely, shallowly punctured throughout and finely, somewhat sparsely pubescent. Length 2.75 mm., breadth 1 mm.

*Holotype* and three paratypes from **Indefatigable Island**, collected July 20-24, 1906, by F. X. Williams.

This species has been carefully checked with all the species in the collection of the British Museum of Natural History and with the literature and seems to differ from all known species. It is near *S. bidentatus* and its relatives but differs by having the anterior prothoracic angles in the form of rounded, transverse tubercles or lobes, not acute spines obliquely or forwardly projecting; and by having the sides of the prothorax serrate, a character seemingly lacking in all other species.

### Family **MONOTOMIDAE**

#### **Bactridium insularis** Van Dyke, new species

Small, narrow and elongate; rufopiceous, with antennae, legs, base, and sides of elytra testaceous. Head moderately convex, regularly, sparsely punctured; eyes rather coarsely granular and somewhat prominent; antennae reaching to base of head and with club of three segments abruptly formed. Prothorax about as long as wide, apex and base truncate, sides straight and feebly converging posteriorly to obtuse hind angles thence oblique to base; disc regularly and sparsely punctured except for median longitudinal area. Scutellum smooth. Elytra about two and a half times as long as broad and twice as long as prothorax, with sides slightly flaring at middle and apex truncate; disc flat with striae not defined but striae punctures coarse, close together, and regularly arranged in rows. Beneath rather coarsely, sparsely punctured in front, more finely and closely on abdomen. Length 2 mm., breadth .6 mm.

*Holotype* and one paratype, collected on **Indefatigable Island**, November 9-15, 1905, by F. X. Williams.

This species seems to be closest to *B. adustum* Reitter but has a proportionally longer and narrower prothorax. It is in fact a much more delicate species, generally narrower and more elongate. than any of the other species.

### Family COLYDIIDAE

#### *Bitoma exarata* (Pascoe)

*Coniophaea exarata* PASCOE, 1866, Jour. Ent. II, p. 91, t. 5, fig. 8.

*Bitoma exarata* (Pascoe), SHARP, Sept. 1891, Biol. Centr.-Amer. Coleopt., Vol. II, Pt. 1, P. 458, t. 14, fig. 19.

Fifteen specimens of what I consider to be the above-mentioned species were collected at Villamil, South Albemarle Island, August 20, 1906, by F. X. Williams. It was first described as collected by Bates in the Amazon Valley, and later listed by Sharp as having been taken in Guatemala by Champion. The specimens agree with Sharp's description. However, they differ from his illustration in several ways. There are short, broad groups of scales (instead of elongate, parallel-sided groups) along the elytral costae; the pronotal costae are sharp, with a line of single golden hairs along the crest, but are not surmounted by rounded groups of scales.

Although Sharp saw the dorsum of Pascoe's type, he did not remount it, and presumed Pascoe to have described the ventral surface erroneously. Pascoe's type was from Ega (now Tefé), Brazil, across the Andes from and some 1050 miles east of Guayaquil, Ecuador. He described the underside as "rugosely punctured, the abdominal segments with a row of longitudinal elevated lines at the base," and the first abdominal segment as longer than usual in the group. None of these statements fit the beetles from Villamil.

### Family LANGURIIDAE

#### *Comptocarpus longicollis* Motschulsky

*Comptocarpus longicollis* MOTSCHULSKY, Schrenk' Reisen Annul., II (2), p. 244.

*Comptocarpus longicollis* Motschulsky, GORHAM, 1887, Biol. Centr.-Amer. Col. VII, p. 6, pl. i, figs. 1-2.

*Comptocarpus longicollis* Motschulsky, BLAIR, 1933, Ann. Mag. Nat. Hist., ser. 10, vol. XI, p. 476.

This Central and South American species is mentioned by Blair, as from Chatham Island, one example, and as stated by him, "(perhaps introduced)."

Family **COCCINELLIDAE****Scymnus galapagoensis** G. R. Waterhouse

*Scymnus galapagoensis* G. R. WATERHOUSE, 1845, Ann. Nat. Hist., XVI, p. 41.

*Scymnus galapagoensis* Waterhouse, LINELL, 1898, Proc. U. S. Nat. Mus., XXI, no. 1143, p. 256.

*Scymnus galapagoensis* Waterhouse, MUTCHLER, 1925, Zoologica, V, no. 20, p. 236.

*Scymnus galapagoensis* G. R. Waterhouse, BLAIR, 1933, Ann. Mag. Nat. Hist., ser. 10, vol. XI, p. 476.

Dr. Blair in 1933, lists three examples from Narborough Island, beaten from mangroves (Collenette), and the California Academy of Sciences has one specimen collected on Indefatigable Island, October 25-28, 1905, by F. X. Williams.

**Cycloneda sanguinea** (Linnaeus)

Numerous specimens of this widely distributed species have been collected in the Islands by various expeditions. Mutchler mentions eight collected by the Templeton Crocker Expedition on Indefatigable Island. The California Academy of Sciences has specimens collected on Charles Island, Clarion Island, and Tower Island.

**Olla abdominalis** (Say)

Eight specimens of this common North American species were mentioned by Mutchler as having been collected by Dr. Wolfgang von Hagen on Indefatigable Island. "ecological Zone C," November 5, 1935.

**Adalia galapagoensis** Van Dyke, new species

Hemispherical, head and pronotum in greater part and entire undersurface black, the elytra testaceous with various black spots and lines, and the tibiae and tarsi rufous. Head with a median triangular black area, widest in front, flanked by testaceous lines, the clypeus also testaceous. Pronotum with an irregular, somewhat hour-glass-shaped median black area, widest at base, and a large round black, eyelike spot at the center of the pallid sides, the surface finely, rather densely but discretely punctured and minutely alutaceous. The elytra testaceous with the suture very finely margined with black, a black spot near the base, another behind and a bit to the outside of it, one or more irregular black marks near the suture at about the middle and an irregular black line laterally, the surface finely and rather densely

punctured and also vaguely alutaceous and shining. The femora in great part piceous and the epipleurae entirely testaceous. Length 4 mm., breadth 3.25 mm.

*Holotype* and twenty-one paratypes, collected on **Charles Island**, at 1000-foot altitude, May 15, 1906, by F. X. Williams; one other specimen from Albemarle Island, 500-foot altitude, collected by J. R. Slevin was also taken.

The markings vary considerably. I have selected as the holotype a specimen which has what I consider as the normal markings. The head may be entirely testaceous, the median black pronotal area may not reach the front margin but divide in a V-like manner or even unite with the eyelike spots at the side, and the elytral markings may be entirely absent or enlarged and connected with each other.

This insect does not seem to agree with any species mentioned by Gorham in the *Biologia Centrali-Americana* nor with *Adalia deficiens* Mulsant, the only other South American species, a species listed as from Chile and Montevideo.

### **Psyllobora bisigma** Van Dyke, new species

Small, testaceous, the mesosternum black and the upper surface ornamented with black markings as follows: the pronotum with a pair of spots at about the center and two spots slightly posterior and more widely separated; and the elytra with a black humeral spot, four elongated spots near the suture, two a little back of the scutellum and two closer together and back of these, these often united to form two elongated patches, one on either side of the suture, and two obliquely placed S-shaped blotches, on the posterior portion of each elytron, the paired markings on each side often united. The elytra rather densely punctured and alutaceous and the pronotum more finely, sparsely and shallowly punctured. Length 2 mm., breadth 1.5 mm.

*Holotype* and nineteen paratypes collected on **Abemarle Island**, 600-foot altitude in August 1906, by F. X. Williams. There is a slight variation in size in the series and some slight modification in the markings, but the general pattern is fairly stable. They were all collected in the yellow flowers of a leguminous plant.

### Family **ALLECULIDAE**

But four species of this family have been reported from the Galapagos Islands. One of these, *Osteia pedinoides* Mäklin, I believe was really collected at Panama and mixed with the specimens taken in the

Islands, as was evidently the case with a number of other truly Central and South American species listed by Blair as collected by the St. George Expedition of 1924.

### **Lobopoda galapagoensis** Linell

*Allecula?* HOWARD, 1889, Proc. U. S. Nat. Mus., XII, p. 191.

*Lobopoda galapagoensis* LINELL, 1898, Proc. M. S. Nat. Mus., XXI, p. 266.

*Lobopoda galapagoensis* LINELL, MUTHLER, 1925, Zoologica, V, no. 20, p. 236.

*Lobopoda galapagoensis* LINELL, BLAIR, 1928, Ann. Mag. Nat. Hist., ser. 10, 1, p. 680.

The California Academy of Sciences has twenty-three specimens collected on Charles Island, at 1000-foot altitude, May 15 and 26, 1906, by F. X. Williams.

### **Allecula galapagoensis** Van Dyke, new species

Of moderate size, graceful in form, with long and delicate antennae and legs, rufopiceous, antennae and legs testaceous, glabrous except for sparse and fulvous pile on labrum, antennae, legs and last ventral segment. Head moderately finely and densely punctured, strongly and transversely impressed behind eyes and to a lesser degree at fronto-clypeal union, front flattened, clypeus transverse and distinctly separated in front and behind by well defined sutures, prominent supra-antennal ridges which are quite smooth near eyes, the labrum rather densely pilose, eyes large and prominent, reniform, coarsely faceted, and separated above by a breadth equal to that of the clypeus, antennae filiform, about reaching middle of elytra, segments 3-11 elongate, the third and fourth segments subequal and about four times as long as broad, the following gradually shorter, and the last four a bit more robust and feebly clavate. Prothorax about a fifth broader than long, apex truncate, base slightly lobed, both with well defined yet narrow margins, sides rather widely arcuate but narrowed towards apex; disc very convex, rapidly declivous laterally, densely punctured, and with a very vague median longitudinal impression. Scutellum semilunar, alutaceous, and finely, vaguely punctured. Elytra almost twice as long as broad and about three times as long as prothorax, broadly ovate, sides sinuate before middle, and broadly arcuate from a little in front of middle to apex; disc very convex, all striae finely but well impressed, the scutellar reaching halfway to middle, striae punctures coarse and well impressed in basal half and much finer on apical half, the intervals quite convex, especially near base and at sides and with very shallow and vague punctures irregularly disposed. Beneath rather coarsely

punctured and rugose in front and alutaceous and very finely punctured behind. The true wings are somewhat reduced in size, therefore not functional. Length 9.5 mm., breadth 4 mm.

*Holotype* female and three paratypes, the first collected on **Indefatigable Island**, in November, 1905, by F. X. Williams, the others on James Island, in December, 1905, also by F. X. Williams.

This species is in perfect accord with the generic description as defined by Champion in the "Biologia Centrali-Americana," and very distinct from any species mentioned by him or noted in the large British Museum of Natural History collection of the literature. It is apparently a more graceful species than usual, with the elytra more narrowed in front and generally cordate, because no doubt of the partial reduction in the size of the wings and resulting atrophy of the supporting structures.

### ***Allecula insularis* Van Dyke, new species**

Rather small, somewhat elongate, brown, elytra somewhat rufous; head, prothorax and underside very finely, sparsely pilose; the elytra clothed with coarser and denser fulvous pile. Head coarsely densely punctured, front flattened, a transverse impression in front of eyes; supra-antennal ridge prominent; eyes reniform, prominent and coarsely faceted and separated above by a width equal to the breadth of the clypeus; antennae filiform (broken). Prothorax almost one-third broader than long, apex transverse, base very feebly arcuate and about a third wider than apex, both base and apex finely margined, sides almost straight and parallel at basal half, evenly arcuate and convergent forwards to apex; disc moderately convex, gradually declivous laterally, and rather coarsely and densely punctured. Elytra twice as long as broad and almost four times as long as prothorax, base a fourth wider than prothorax, sides almost straight and parallel from humeri to posterior third, thence arcuate and convergent to apex; disc moderately convex, striae finely impressed and finely and closely punctured, the punctures much finer on apical half, intervals feebly convex, alutaceous, finely and irregularly punctured with fine semierect fulvous hairs arising from them. Beneath coarsely punctured and rugose in front, alutaceous and finely and sparsely punctured behind. Legs of moderate length. Apparently fully winged. Length 6 mm., breadth 2.25 mm.

*Holotype*, collected on **Indefatigable Island**, May 7, 1932, by M. Willows, Jr., of the Templeton Crocker Expedition of 1932. Three

other specimens collected on Albemarle Island, two on April 24-27, 1906, and one on Cowley Mt., August 9-13, 1906, by F. X. Williams, have been associated with the type.

### ***Cteisa pedinoides* Mäklin**

*Cteisa pedinoides* (Dejean) MÄKLIN, Act. Soc. Fenn., X, p. 681.

*Cteisa pedinoides* Mäklin, CHAMPION, 1888, Biol. Centr.-Amer. Zoo. Insecta. IV, 1, p. 465, pl. XXI, fig. 13.

*Cteisa pedinoides* Maklin, BLAIR, 1933, Ann. Mag. Nat. Hist., ser. 10, vol. XI, p. 481.

One specimen recorded by Blair as from Chatham Island. This was supposedly collected by the St. George Expedition of 1924, but as above stated I believe that it was really taken on the mainland and mixed with island specimens.

### Family **TENEBRIONIDAE**

The family Tenebrionidae is well represented in the Islands. Two of the larger genera, *Stomion* Waterhouse and *Pedonocerus* Waterhouse, are confined to them, and a third genus, *Ammophorus* Guérin-Méneville, has the greater number of its species restricted to them, the others including one from Panama, several from the west coast of South America, and one from the Island of Oahu of the Hawaiian Islands, undoubtedly introduced within historic times. These three genera with species on practically every one of the islands, and mostly distinct and often showing a great deal of variation, have presented us with one of the most interesting groups for the study of such problems as variation, evolution and isolation; other genera with a limited number of species are also represented, including several more or less cosmopolitan.

#### Genus **Stomion** G. R. Waterhouse

*Stomion* G. R. WATERHOUSE, 1845, Ann. Nat. Hist., XVI, pp. 27-29

The genus *Stomion* is now considered to belong to the subfamily Tentyriinae and the tribe Eurymetopini, the greater proportion of the members of the latter being Californian.

At the time G. R. Waterhouse established the genus, he described three species: *S. galapagoensis*, *S. helopoides*, and *S. laevigatum*, the first of which should be considered as the genotype. In 1898, Linell described three more: *S. carinatipenne*, *S. piccum*, and *S. bauri*. The first two have been considered by Blair as but synonyms or at most



slight variants of *S. galapagoensis*, he having paratypes in his hands to compare with Waterhouse's types. Linell's *S. bauri*, placed questionably as a synonym of *S. laevigatum* Waterhouse by Blair, I am inclined to believe is without doubt such. Specimens from Albemarle Island, the type locality for *S. bauri*, cannot be separated from typical specimens of *S. laevigatum* from James Island, compared with the type in the British Museum of Natural History. What Linell took to be *S. laevigatum* was described by Blair as *S. linelli*, being quite different in structure though superficially resembling the former.

In the museum of the California Academy of Sciences which contains the large series collected by the Academy's Expedition of 1905-06 as well as that secured by the Tempelton Crocker Expedition of 1932, representatives of all described species are present. Selected specimens of these I have compared, with the assistance of Dr. Blair, with the types in the British Museum of Natural History, during 1932 and 1933. In addition to the above, there are specimens of five other species, two the most divergent of the genus and the others forming a more or less related group somewhat similar to *S. galapagoensis*. These will be described in the following pages.

When the species are considered in relation to their distribution, certain very interesting and significant facts are brought out. The two most divergent species: *S. rugosum* and *S. longicornis* are found, the first on Abingdon and Bindloe, two moderate-sized and closely associated islands, to the north of the main group; and the second, on Hood Island, the most southeastern of the group. The first is a lone tenant as far as the genus goes, of the island, but *S. galapagoensis* is to be found in association with *S. longicornis*. The somewhat elongate group with pronounced sulcate elytra including *S. cribricollis*, *S. obesum*, and *S. longulum*, has the first species restricted to Wenman and Culpepper, two small islands somewhat isolated and to the northwest of the main group; the second species confined to Duncan and Brattle islands, two minor islands situated in the channel between the large island of Indefatigable and the southern part of Albemarle; while the last is to be found on both these large islands. *Stomion helopoides* has been found on Chatham Island as well as on the small island of Tower, far to the north of it, Barrington, somewhat to the west and Gardner, near Charles, to the southwest of it, in what might be called, an eastern group of islands. The best known species, *S. galapagoensis*, is found on Chatham, Hood, and Charles as well as on the small islands of Champion near Charles, and Gardner, also near Charles, a southern group. Of the two species of the smooth group, *S. laevigatum* is found on James Island, on the northern part of Albe-

marle as well as on Cowley Island, a very small island near the eastern coast of the above, a north central location; while *S. linelli* is restricted to Indefatigable and the small islands of South Seymour close to its northeastern extremity, a central location. Other peculiarities will be mentioned while discussing the individual species.

***Stomion galapagoensis* G. R. Waterhouse**

Plate III, figure 1

*Stomion galapagoensis* G. R. WATERHOUSE, 1845, Ann. Nat. Hist., pp. 29-30.

*Stomion galapagoensis* G. R. Waterhouse, C. WATERHOUSE, 1877, Proc. Zoo. Soc., V, pp. 79 and 82.

*Stomion galapagoensis* G. R. Waterhouse, HOWARD, 1889, Proc. U. S. Nat. Mus., XII, no. 77, p. 192.

*Stomion galapagoensis* G. R. Waterhouse, LINELL, 1898, Proc. U. S. Nat. Mus., XXI, no. 1143, p. 262.

*Stomion galapagoensis* G. R. Waterhouse, MITCHLER, 1925, Zoologica, V, no. 20, pp. 228, 236.

*Stomion galapagoensis* G. R. Waterhouse, BLAIR, 1928, Ann. Mag. Nat. Hist., ser. 10, 1, p. 672.

*Stomion galapagoensis* G. R. Waterhouse, BLAIR, 1933, Ann. Mag. Nat. Hist., ser. 10, XI, pp. 477-478.

*Stomion carinipenne* LINELL, 1898, Proc. U. S. Nat. Mus., XXI, no. 1143, p. 262.

*Stomion carinipenne* Linell, MITCHLER, 1925, Zoologica, V, no. 20, p. 236.

*Stomion carinipenne* Linell, BLAIR, 1933, Ann. Mag. Nat. Hist., ser. 10, XI, p. 477.

*Stomion piccum* LINELL, 1898, Proc. U. S. Nat. Mus., XXI, No. 1143, pp. 262-263.

*Stomion piccum* Linell, MITCHLER, 1925, Zoologica, V, no. 20, p. 236.

*Stomion piccum* Linell, BLAIR, 1933, Ann. Mag. Nat. Hist., ser. 10, XI, p. 477.

Large, robust, dull black, antennae, legs and undersurface varying from rufopiceous to piceous. Head broad, flattened or shallowly excavated in front, coarsely and rather closely punctured, the arcuate impression at sides of clypeus well marked; antennae almost reaching hind angles of prothorax, third segment long, almost as long as fourth and fifth together; intermediate segments hardly more than twice as long as broad, the three terminal segments forming a loose club, triangular and longer than broad. Prothorax transverse, over a fourth broader than long, base bisinuate with broad median lobe, apex deeply emarginate, generally broadest at base and with sides arcuate and gradually convergent forwards, the hind angles rectangular and the front angles somewhat acute and prominent, lateral and basal margins fine and complete, extending to sides of front; disc evenly convex,

rather coarsely and somewhat closely punctured, the punctures, however, well spaced and generally finer towards sides and base. Scutellum small and transverse. Elytra one-fourth longer than broad, slightly wider at base than prothorax, broadest at middle, humeri subangular, sides evenly and moderately arcuate from base to beyond middle then rather abruptly oblique and convergent to apex; disc very convex, the general surface otherwise variable though always with the intervals more or less convex or even carinate, the intervals also generally much broader than striae or sulci, the striae well impressed and with coarse, rounded, well-spaced punctures regularly arranged, the intervals finely and often obscurely punctured, the punctures generally in an irregular double series. Beneath with all thoracic sclerites very coarsely, somewhat variolately punctured, the abdomen finely and sparsely punctured. Legs rather long and more or less coarsely, closely punctured. Length 9-11 mm., breadth 4.5-6 mm.

This species has been previously reported from most of the southeastern islands such as Charles (Linell and Blair), Chatham (Linell, Mutchler, Blair), and South Seymour (Mutchler). The California Academy of Sciences has numerous specimens from Charles and Chatham as well as from Hood and the small islands, Champion and Gardner, near Charles. It is apparently quite common and likewise very variable. The usual form such as is generally to be found on Charles and Chatham is piceous or rufopiceous in color, with the elytral intervals moderately convex and the striae and the striaal punctures well impressed. *Stomion piceum* Linell is merely a phase with the intervals less convex and *S. carinipenne* Linell, one with them feebly carinate. Both of these were placed as synonyms of *S. galapagoensis* by Blair (1933) and properly so. The specimens from Gardner and Champion islands have the elytral intervals more convex than usual while those from Hood Island are the most divergent of all, having the pronotal punctures somewhat coarser and the elytral intervals decidedly carinate, especially posteriorly. This last approaches the following, a peculiar form resident in the northeastern part of Hood, so distinct in many ways that I am going to describe it as a subspecies. It may even prove to be a good species.

***Stomion galapagoensis punctipennis* Van Dyke, new subspecies**

Similar in size and general form to *S. galapagoensis* especially to the more carinate phase which is to be found on Hood Island. Its distinctive features are that it is more shining, its prothorax slightly narrower at the base, therefore widest a short distance in front of base,

the pronotum more coarsely and closely punctured, in places almost eribrate, the elytra with the stria punctures very coarse and sharply impressed, the intervals carinate behind but almost flattened in front, and quite coarsely irregularly punctured, the punctures being sharply impressed and but slightly smaller in size than those of the pronotum; the undersurface also more distinctly punctured than the usual specimens of *S. galapagoensis*.

*Holotype* and paratypes from a small series of specimens collected on the northeastern part of **Hood Island**, during February, 1906, by F. X. Williams.

The characters that seem to isolate this form are the narrowed prothorax and strong punctuation of pronotum and elytral intervals. If it were not for the fact that some of the more typical examples of *S. galapagoensis* approached it in this last regard, I would consider it to be a very distinct species. It is easily recognized.

### ***Stomion helopoides* G. R. Waterhouse**

Plate III, figure 2

*Stomion helopoides* G. R. WATERHOUSE, 1845, Ann. Nat. Hist., XVI, p. 30

*Stomion helopoides* G. R. Waterhouse, C. WATERHOUSE, 1877, Proc. Zoo. Soc., V, p. 82.

*Stomion helopoides* G. R. Waterhouse, HOWARD, 1889, Proc. U. S. Nat. Mus., XII, no. 77, p. 192.

*Stomion helopoides* G. R. Waterhouse, LINELL, 1898, Proc. U. S. Nat. Mus., XXI, no. 1143, p. 263.

*Stomion helopoides* G. R. Waterhouse, MUTCHLER, 1925, Zoologica, V, no. 20, p. 236.

*Stomion helopoides* G. R. Waterhouse, BLAIR, 1933, Ann. Mag. Nat. Hist., ser. 10, XI, p. 477-478.

Medium sized, robust, black to rufopiceous, legs, antennae and undersurface rufous. Head broad, feebly excavated in front; coarsely, closely, somewhat cribrately punctured, with shallow fovea on front and the arcuate impressions at sides of clypeus very distinct; antennae extending slightly behind middle of prothorax, the segments about as in preceding species. Prothorax three-eighths broader than long, base bisinuate, median lobe feeble, apex moderately emarginate, widest slightly behind middle and with sides evenly rounded though more convergent in front, hind angles obtuse and front angles right angled, the marginal bead as in preceding species; disc evenly convex and moderately coarsely, somewhat closely punctured, the general surface minutely alutaceous. Scutellum small and transverse. Elytra two-sevenths longer than broad, wider at base than base of prothorax,

humerali obtusely rounded, sides gradually arcuate and narrowed to apex; disc very convex, the striae punctures large and regularly arranged but striae vaguely impressed at most, intervals flat or feebly convex and with an irregular double row of moderate-sized punctures, about one-half size of striae punctures. Beneath with prosternum and meso- and metathoracic sclerites coarsely and sparsely punctured, the propleurae vaguely punctured, and the abdomen finely and sparsely punctured. Legs moderately long and more or less coarsely punctured as usual. Length 8.5–9 mm., breadth 4–4.75 mm.

The locality for the Darwin specimens was not given. The specimens in the California Academy of Sciences were collected on Chatham, Charles, Hood, Tower, and Gardner near Charles. A Chatham Island specimen, compared with the type, agrees with it in every regard. The Tower and Gardner specimens are slightly divergent. The main characteristic features of this species are its rather even contour with punctuation very distinct, both of striae and intervals as well as pronotum. As indicated in the original description and in its name, it bears a great resemblance to certain species of *Helops*. Along the southern California coast and on the adjacent islands, there are a number of small, robust, sand dune inhabiting species of *Helops* such as *H. bachei* Le Conte, *H. blaisdelli* Casey, and so forth, which closely resemble this beetle.

### **Stomion obesum** Van Dyke, new species

Moderate in size, stocky, very convex, dull black or piceous, with antennae, legs, and undersurface rufopiceous. Head broad, slightly concave in front; coarsely, closely and somewhat strigosely punctured, the arcuate impression at sides of clypeus distinct; antennae not quite reaching hind angles of prothorax and with segments about as in preceding species. Prothorax a third wider than long, base bisinuate with median lobe distinct, apex shallowly emarginate, broadest at base in typical forms or behind middle in variants, sides rather evenly arcuate and gradually convergent from base to apex, sometimes feebly sinuate in front of apical angles, basal angles right and apical angles somewhat acute and projecting, the marginal bead as usual; disc very convex, suddenly declivous to basal margin, minutely alutaceous and rather coarsely and closely punctured over entire surface, in places somewhat aciculate. Scutellum small and transverse. Elytra a third longer than broad, widest at middle, slightly broader at base than prothorax, sides evenly arcuate to beyond middle thence almost straight and convergent to rather acute apex; disc very convex, striae well impressed, rather finely and regularly punctured, intervals subcarinate throughout in

typical specimens, but feebly subearinate and even only convex behind in divergent forms and very finely, irregularly yet distinctly punctured. Beneath, thoracic sclerites coarsely punctured, the abdomen much more finely and sparsely punctured in front, more closely behind. Legs of moderate length and rather coarsely punctured. Length 8 mm., breadth 4.25 mm.

*Holotype* and two paratypes from **Duncan Island**, collected June 14-15, 1906, by F. X. Williams. With this species, I have associated as weak varieties seven specimens from Brattle Island, collected October 30, 1905, by F. X. Williams and a small series from Barrington Island, collected October 19-24, 1905, also by F. X. Williams. The specimens from Brattle Island have the pronotal punctures somewhat finer and the elytral intervals less carinate in front; and the Barrington specimens have the intervals much broader and more evenly convex, almost flat in front, and the body as a whole noticeably broader.

This species is in general smaller than the smallest *S. galapagoensis* but with both prothorax and elytra much more convex. The dull and somewhat sericeous appearance and gibbous prothorax most readily separate this species.

### ***Stomion cribricollis* Van Dyke, new species**

Plate III, figure 3

Elongate elliptical, moderate in size, dull black above or with forebody feebly shining, underside rufopiceous and antennae and legs bright red. Head rather broad; coarsely, closely, cribrately punctured; flattened or feebly concave in front and with arcuate impressions at sides of clypeus well marked, antennae almost reaching hind angles of prothorax and with segmental proportions as usual. Prothorax subquadrate, only about one-seventh broader than long, base bisinuate with the median lobe moderate in size, apex slightly emarginate, hind angles right angled, front angles acute, sides slightly arcuate in basal half or even sinuate before hind angles and a bit more rounded and slightly convergent forwards, the marginal bead as usual, disc moderately convex and coarsely and closely as well as more or less cribrately punctured. Scutellum very small and transverse. Elytra about a third longer than broad, slightly broader at base than prothorax, sides rather evenly arcuate to beyond middle, thence suddenly convergent to acute apex, disc very convex, striae deeply impressed forming sulci, finely and regularly punctured, intervals carinate, more narrowly and sharply so on declivity with exception of sutural which are flattened, more or less transversely rugose and

feebly interrupted, and irregularly punctured with minute setae arising from the punctures. Beneath, the thoracic sclerites coarsely and in most cases closely punctured, the abdomen finely and sparsely punctured in front and more coarsely and closely on last two segments. Legs rather delicate and finely and sparsely punctured. Length 8 mm., breadth 4 mm.

*Holotype* male, allotype female and numerous designated paratypes from a series of twenty-nine specimens collected on **Wenman Island**, September 24, 1906, by F. X. Williams. There is also a series of twenty specimens collected on the adjacent Culpepper Island, September 25, 1906, by F. X. Williams, which do not differ in any appreciable manner from the preceding hence are associated with them.

The species stands out from its fellows because of its narrow, elongate body with sharply pointed elytra; dull, opaque appearance; coarse, cribrately punctured pronotum; carinate and finely punctured elytra; and clear red legs. Though it should be associated with *S. obscurum* and *S. longulum* because of its general facies and carinate elytra, its other characters mark it as a most distinct species.

### ***Stomion longulum* Van Dyke, new species**

#### Plate III, figure 4

Elongate, subcylindrical, feebly shining, black with antennae and legs and also undersurface generally more or less rufopiceous. Head broad, flattened, or feebly concave in front; coarsely, rather closely punctured and with arcuate impressions at sides of clypeus but moderately well defined; the antennae reaching but little behind middle of prothorax. Prothorax about one-sixth broader than long, widest at middle, base bisinuate with median lobe moderately well defined, apex slightly and evenly emarginate, sides rather evenly arcuate, slightly more narrowed in front than behind; disc evenly convex, distinctly but not coarsely and rather closely punctured, the surface minutely alutaceous, the marginal bead sharply defined at base, elsewhere as usual. Elytra three-tenths longer than broad, very slightly broader at base than base of prothorax, sides feebly and evenly arcuate to beyond the middle, thence convergent to apex; disc moderately convex, striae deeply impressed forming sulci, striae punctures obsolete, intervals very convex, subcarinate and narrowed behind and with punctures very fine or more or less obsolete. Beneath very coarsely and closely punctured in front, finely and sparsely behind. Legs of moderate length and rather coarsely punctured. Length 8 mm., breadth 3.5 mm.

*Holotype* and nine paratypes, collected on **Indefatigable Island**, May 5-7, 1932, by M. Willow, Jr., of the Templeton Crocker Expedition of 1932, and on October 25-28, 1905, by F. X. Williams. I have also associated with the above a series of over a hundred specimens collected near Villamil, Albemarle Island, March 4-14, 1906, by F. X. Williams, which are not appreciably different from them.

This species is one of the smallest of the genus and proportionally the narrowest and most elongate. It belongs in association with *S. cribricollis* and *S. obesum* but differs by having in addition to the above-mentioned features, much finer pronotal punctures and a practical absence of elytral punctuation. In this last regard, it simulates *S. laevigatum* and *S. linelli* but differs greatly by having the elytra sulcate. From *S. bauri* Linell which is also to be found on Albemarle Island and which both Blair and I have suppressed as a synonym of *S. laevigatum*, it differs by its marked sulcate and subearinate elytra, practically smooth in *S. laevigatum*. The California Academy of Sciences has specimens of both *S. laevigatum* and *S. longulum* from Albemarle Island.

### ***Stomion laevigatum* G. R. Waterhouse**

Plate III, figure 5

*Stomion laevigatum* G. R. WATERHOUSE, 1845, Ann. Nat. Hist., p. 30

*Stomion laevigatum* G. R. Waterhouse, C. WATERHOUSE, 1877, Proc. Zoo. Soc., V, p. 82.

*Stomion laevigatum* G. R. Waterhouse, MUTCHLER, 1925, Zoologica, V, no. 20, pp. 228, 236.

*Stomion laevigatum* G. R. Waterhouse, BLAIR, 1928, Ann. Mag. Nat. Hist., ser. 10, 1, p. 672.

*Stomion laevigatum* G. R. Waterhouse, BLAIR, 1933, Ann. Mag. Nat. Hist., ser. 10, XI, pp. 477-478.

*Stomion bauri* LINELL, 1898, Proc. U. S. Nat. Mus., XXI, no. 1143, p. 263.

*Stomion bauri* Linell, MUTCHLER, 1925, Zoologica, V, no. 20, p. 236.

*Stomion bauri* Linell, BLAIR, 1933, Ann. Mag. Nat. Hist., ser. 10, XI, p. 477.

Rather small, black, feebly shining, antennae legs and undersurface rufopiceous. Head broad, feebly excavated in front, rather coarsely and somewhat closely punctured on front, more finely and closely along front margin, impressions at sides of clypeus well marked, general surface alutaceous; antennae extending to posterior third of prothorax. Prothorax one-third broader than long, widest at middle, base bisinuate and with median lobe broad but feeble, apex distinctly emarginate, sides feebly arcuate from base to beyond middle and thence almost straight and convergent to apex, hind angles right angled, front acute



and prominent; disc convex, rather dull, minutely alutaceous and very finely and somewhat indistinctly as well as sparsely punctured, the marginal bead well marked. Scutellum small and transverse. Elytra over a fifth longer than broad, subcordate, widest at posterior third, humeral angles prominent but blunt, sides feebly arcuate and gradually wider to posterior third, then convergent to acute apex; disc moderately convex, almost smooth, the striae being but obscurely impressed, the stria punctures very fine, sometimes imperceptible, and the intervals in general but vaguely elevated though sometimes feebly convex posteriorly. Beneath coarsely, closely punctured in front, minutely punctured behind or impunctate except on last segment. Legs somewhat coarsely punctured. Length 6-8 mm., breadth 3-4 mm.

The locality for the type was not given by G. R. Waterhouse. Blair, however, cites Charles and James Islands. Linell described *S. bauri* as from Albemarle Island. The California Academy of Sciences has specimens from James Island, several of which were compared with the type and found to agree absolutely, from Cowley Island near Albemarle and from Tagus Cove, Albemarle Island. The James Island specimens were collected from December 21, 1905, to January 5, 1906, the Cowley Island, August 9-13, 1906, and the Tagus Cove specimens, April 1906, all by F. X. Williams. In addition M. Willows, Jr., of the Templeton Crocker Expedition collected specimens at Tagus Cove, May 25, 1932. In all we have a series of over twenty specimens.

This species was misunderstood by Linell. As explained by Blair, it was thought to be undescribed and so called *S. bauri*, and the other smooth species considered to be *S. laevigatum*. The latter was later described by Blair as *S. linelli*. The two species are both quite smooth, standing out distinctly as a result from the other members of the genus, but each is distinct from the other as shown by Blair, by the proportions of the body.

### ***Stomion linelli* Blair**

Plate III, figure 6

*Stomion linelli* BLAIR, 1933, Ann. Mag. Nat. Hist., ser. 10, XI, p. 478.

*Stomion laevigatum* LINELL, 1898, Proc. U. S. Nat. Mus., XXI, no. 1143, p. 263.

Of moderate size, robust, black, feebly shining; antennae, legs and undersurface somewhat rufo-piceous. Head broad, feebly excavated in front; coarsely, rather closely punctured; impressions at sides of clypeus well defined; antennae about reaching posterior third of prothorax. Prothorax slightly over one-third wider than long, broadest at base, base bisinuate, median lobe broad and conspicuous, apex broadly

emarginate, sides feebly and evenly arcuate from base and gradually convergent forwards, sometimes feebly sinuate just before apex, hind angles right angled or feebly obtuse, front angles acute and prominent, disc very convex, finely and closely punctured, minutely alutaceous and with marginal bead as usual. Scutellum small and transverse. Elytra one-fifth longer than broad, ovate, widest behind middle, sides evenly arcuate to posterior third thence rapidly convergent to apex; disc very convex, striae and striae punctures vaguely impressed, intervals flat and minutely and vaguely punctured at most. Beneath coarsely, closely punctured in front but with punctures less sharply defined than usual, behind finely and sparsely punctured. Legs rather coarsely punctured. Length 7-8 mm., breadth 4-4.5 mm.

This species is listed by Blair as follows: "Eden Id., 3 ex. (Bateson); Indefatigable Id., 3 ex. (Collette); Tower Is. (1 ex. det. by Linell [corrected by Blair to Mutchler] as *laevigatum* Waterh.). Also in the California Academy Collection." The California Academy of Sciences specimens were collected on S. Seymour Island, 2 specimens, November 22, 1905, by F. X. Williams and on Indefatigable Island, November 17-19, 1905, by F. X. Williams. On the latter island a series of over forty specimens was collected. One of these Blair has designated as a *paratype*.

This species is somewhat smooth like *S. laevigatum* and could only be confused with that species as it was by Linell. As stated by Blair, it "resembles *S. laevigatum* in sculpture but of much broader build, widening gradually from in front to the posterior third of the elytra. In *laevigatum* the thorax is but little wider at the base than at the apex, and the elytra widest about the middle, giving the insect a more elongate, subparallel form rather than the ovate form of *linelli*." This species is in shape also much like *S. obesum* but lacks the dull appearance and sulcate elytra.

### ***Stomion longicornis* Van Dyke, new species**

Plate III, figure 7

Large, robust, smooth and shining, minutely and sparsely pilose especially on head, elytral declivity and undersurface black with antennae, legs and undersurface rufopiceous; the antennae and legs long and delicate. Head broad, broadly excavated in front, sparsely pilose, rather coarsely and closely and also more or less aciculate punctured, the arcuate impressions at sides of clypeus broad; antennae long and delicate, extending to hind margins of prothorax. Prothorax fully a third broader than long, widest at middle, base slightly bisinuate with median lobe broad though feebly developed,

apex evenly arcuate, sides evenly arcuate from base to apex but more narrowed anteriorly, hind angles slightly obtuse, front angles fairly acute; disc moderately convex, rather coarsely and closely and also more or less aciculate punctured, very shining and very sparsely pilose in front, marginal bead as usual. Scutellum small and semilunar in shape. Elytra one-fifth longer than broad, widest at middle, sides strongly arcuate, suddenly convergent to apex; disc very convex, striae feebly impressed but with rather coarse and closely placed as well as very distinctly impressed striae punctures; intervals broad, flat or feebly convex at most, minutely and irregularly punctured, each interstrial puncture with a short and very fine hair arising from it. Beneath very coarsely and closely and also shallowly punctured in front, rather finely and sparsely punctured on abdomen, and minutely and sparsely pilose. Legs long and delicate, rather finely punctured, the femora with pronounced lobes at the apex beneath. Length 8 mm., breadth 4 mm.

*Holotype* male and several designated paratypes from a series of fourteen specimens collected on **Hood Island**, February, 1906, by F. X. Williams. Some of the specimens are much larger than the type.

This species is one of the most divergent of the species of *Stomion*, its long antennae and legs, robust body, large and transverse prothorax, very shining surface, and distinctive type of sculpturing readily separate it. The strigose punctuation of the pronotum is pronounced and the lobes at the outer part of the femora are more prominent than in any other species. It is in general appearance more like some of the genera of the Helopini than like its own relatives. Its characters are, however, those of *Stomion*.

### ***Stomion rugosum* Van Dyke, new species**

Plate III, figure 8

Of moderate size, robust, very convex, black with rufous antennae and legs, very rugose above and opaque. Head broad, flattened, coarsely and closely and also cribrate punctured, somewhat rugose, with arcuate impressions at sides of elypeus moderately well defined; antennae rather short, extending only to middle of prothorax. Prothorax over a third broader than long, widest at base, base bisinuate, median lobe moderately developed, apex shallowly emarginate, sides evenly arcuate and gradually convergent from base to apex, feebly sinuate just before at times; disc convex, very coarsely and closely as well as cribrate punctured and rugose, the marginal bead evident but more poorly defined than usual.

Scutellum small and transverse. Elytra a third longer than broad, slightly wider at middle, sides evenly though but moderately arcuate to beyond the middle thence rather suddenly convergent to acute apex; disc very convex, striae deeply impressed forming sulci, rather coarsely and regularly punctured; intervals prominent, carinate, finely irregularly punctured and transversely rugose. Beneath very coarsely, closely punctured in front and almost as coarsely and closely punctured behind. Legs also quite coarsely punctured. Length 9 mm., breadth 4.5 mm.

*Holotype* and a series of designated paratypes from eighty specimens collected on **Abingdon Island**, during September 1906, by F. X. Williams.

This is a most distinct species, standing out from among the other species of the genus because of its opaqueness, markedly rugose upper surface and very coarse abdominal punctuation.

#### KEY TO SPECIES OF GENUS STOMION G. R. WATERHOUSE

1. Pronotum finely or moderately coarsely punctured, punctures distinctly separated though often approximate..... 2
- Pronotum with punctures coarse and anastomosing, entire upper surface very rugose and opaque..... *S. rugosus*, new species
2. Large, robust, prothorax very transverse, over one-third broader than long, punctures at least moderately coarse and well spaced, striae punctures of elytra coarse and regular..... 3
- Of moderate or small size, 9 mm. or less in length, generally narrow and somewhat elongate; prothorax more equally quadrate and more numerous punctured; striae punctures of elytra fine or more or less obliterated..... 6
3. Dull, intermediate antennal segments barely twice as long as broad, pronotal punctures somewhat coarse, round and well separated on disc, punctures of elytral intervals moderately coarse..... 4
- Very shining, antennae long, intermediate segments more than twice as long as broad, pronotal punctures fine, close together on disc and somewhat acuminate, punctures of elytral intervals fine but distinct and very numerous..... *S. longicornis*, new species
4. Prothorax widest posteriorly or at most slightly narrowed before base; elytral striae well impressed, generally more or less sulcate and with punctures large and regularly arranged..... 5
- Prothorax widest behind middle, distinctly narrowed toward base; elytral striae but feebly impressed at most, intervals broader than striae, not elevated, and with punctures near base almost as large as those of striae; general surface smoother and more shining than the two following species..... *S. helopoides* G. R. Waterhouse

5. Dull, prothoracic punctures but moderately coarse; punctures of elytral intervals fine, contrasting greatly in size with those of striae.....  
.....*S. galapagoensis* G. R. Waterhouse
- Somewhat shining, prothoracic punctures very coarse, sides of prothorax always arcuate and somewhat narrowed towards base; punctures of elytral striae very coarse and of intervals also quite coarse especially at base .....  
.....*S. g. punctipennis*, new subspecies
6. General surface smooth and even, without elevated intervals or carinae; punctures of pronotum fine, of elytra generally obliterated or very fine and vague..... 9
- General surface markedly sculptured, elytral carinae prominent, at least on declivity; punctures of pronotum coarse or moderately distinct, of elytra evident at least in striae ..... 7
7. Pronotal punctures coarse, striae punctures very evident, those of intervals or carinae distinct, fine and numerous; general surface subopaque, legs red ..... 8
- Pronotal punctures numerous and but moderately coarse, striae punctures obscure, those of intervals or carinae very fine or more or less obscure; general surface feebly shining, legs rufopiceous to black .....  
.....*S. longulum*, new species
- 8 Head and pronotum coarsely, approximately punctured; prothorax broadest at base and moderately convex, elytra elongate cordate, the sulci as broad as intervals, the punctures of both about equally distinct ..  
.....*S. craticollis*, new species
- Head and pronotum coarsely, densely, but not approximately punctured, prothorax broadest behind middle, very convex, elytra subcordate, sulci narrower than intervals and with punctures of latter very fine, much smaller than those of striae, surface somewhat sericeous  
.....*S. obesum*, new species
9. Narrower, more oblong, prothorax widest behind middle, sides rounded .....  
.....*S. laevigatum* G. R. Waterhouse
- Broader, more ovate; prothorax widest at base, arcuately narrowed to front. ....  
.....*S. luceti* Blau

### (Genus *Parepitragus* Casey)

*Parepitragus* CASEY, 1907, Proc. Wash. Acad. Sc., IX, p. 578.

This genus was separated by Casey from the extensive American genus *Epitragus*.

### *Parepitragus fuscipes* (Latreille)

*Epitragus fuscipes* LATREILLE, 1833, Humb. et. Bonpl. Voy. II, p. 64, t. 34, fig. 5.

Of moderate size, elongate, dark piceous; elytra, antennae and legs rufopiceous; sub-glabrous, the upper surface sparsely clothed with very minute hair, the undersurface a bit more evidently pilose. Head feebly convex, moderately punctured, the epistoma more finely and densely punctured and feebly produced at the middle with truncate

apex; eyes convex, prominent, coarsely faceted with sharply defined supraorbital ridge in front; antennae with outer segments hardly broader than those in front and extending to hind angles of prothorax. Prothorax over one-third broader than long, apex transverse with front angles obtuse, not projecting, base bisinuate with well defined median lobe, sides very feebly arcuate from base to beyond middle thence more rounded and convergent to apex, hind angles sharply rectangular; disc moderately convex, evidently but not closely punctured, a bit denser laterally, a very feeble median longitudinal impression in front and well marked basal impressions between middle and hind angles. Scutellum small, rounded. Elytra three-eighths longer than broad and two and two-thirds longer than prothorax and about a fourth broader at base than prothorax, sides almost straight to posterior third thence arcuate to apex; disc convex, striato-punctate, the punctures coarse and well spaced basally and rapidly finer towards apex, intervals feebly convex and finely and irregularly punctured, the sutural interval depressed towards apex, and the entire apical area dull and opaque in contrast to the shining basal portion. Beneath more or less densely punctured especially on abdomen. All tarsi with tufts of long dense pubescence beneath. Length 12 mm., breadth 4.75 mm

This species has not been previously recorded from the Galapagos Islands. The single specimen from which the description was drawn was collected on Chatham Island, April 18, 1932, by M. Willows, Jr., of the Templeton Crocker Expedition of 1932. It was carefully compared with specimens of *P. fuscipes* in the British Museum of Natural History collection and found to agree perfectly. This species which was described as from the United States of Colombia, is listed in the Junk Catalogus Coleopterorum by Hans Gebien as in the genus *Epi-tragus* where it was originally placed. Dr. Blair, in rearranging the British Museum species, placed it in Casey's genus *Parcepitragus*. It most certainly possesses the essential characters used by Casey in defining his genus such as the produced epistoma, convex, prominent and coarsely faceted eyes, with distinct supraorbital ridge, the prothorax truncate anteriorly with front angles obtuse and not prominent, and the tarsi with tufts of long dense pubescence beneath.

### Genus **Ammophorus** Gúerin-Ménéville

*Ammophorus* GÚERIN-MÉNEVILLE, 1830, Voyage Coquille, Ent., II, p. 94, pl. 4, fig. 4.

*Ammophorus* Gúerin-Ménéville, SOLIER, 1838, Anns. Soc. Ent. Fr., VIII, pp. 34-40, pl. 2, fig. 1-5.

*Selenomma* Solier, DEJEAN, Cat., ed. 2, p. 183.

The genus *Ammophorus* is well defined by Solier. It belongs in the tribe Scaurini and is supposedly most closely related to the three California genera: *Eulabis* Eschscholtz, *Epantius* Leconte and *Apsena* Leconte, which have been monographed by Blaisdell (1932). It is significant that all of these genera are confined to the western coast of the Americas and the adjacent islands, *Ammophorus* to South America, and the others to North America. No close relatives or intermediates are to be found in intermediate territory.

*Ammophorus*, though based upon a mainland South American species, *A. peruvianus*, Gúerin-Méneville, the genus is extensively represented in the Galapagos Islands and as characteristic a coleopterous genus of the Archipelago as are *Stomion* and *Pedonocces*, which are restricted to it. Five good species have been described to date from the South American continent: *A. peruvianus* Gúerin-Méneville in 1834, from Peru; *A. costatus* Gúerin-Méneville in 1834, from Peru; *A. rubripes* Solier in 1838, from Peru, also listed from Chile; *A. spinolae* Solier in 1838, from Peru; and *A. denticollis* Boheman in 1858, from Panama. Boheman also described *A. insularis* in 1858, from Hawaii (Sandwich Islands). This last also occurs in the Galapagos Islands and I am confident was carried from there to the Hawaiian Islands within historic times, probably in the gravel ballast, by whalers. It is definitely known that these regularly visited the Galapagos Islands for cargoes of tortoises for food, and later visited the Hawaiian Islands, to try out their catch of whale blubber. Its present distribution in the latter Archipelago is extremely local, near Waikiki on the outskirts of Honolulu. This locality is also close to the old whaling anchorage region. Another interesting fact in this connection is that *Ammophorus insularis* Boheman was not recovered in the Hawaiian Islands until quite recently. Neither Blackburn nor Perkins, who collected extensively in the Islands, found it.

The described Galapagos Island species are *A. galapagoensis*, *A. bifoveatus*, and *A. obscurus*, all described in 1845 by G. R. Waterhouse from material collected by Charles Darwin; *A. cookoni* C. Waterhouse, described in 1877; and *A. caroli* Linell which is an undoubted synonym of the preceding, described in 1898. The California Academy of Sciences has a very large series of specimens from the Galapagos Islands, collected in the 1905-1906 Expedition of the Academy and the Templeton Crocker Expedition of 1932. Among these are representatives of all described species from the Islands as well as a number of species which I consider as new and which will be described in this paper. The Waterhouse types are in the British Museum of Natural History. These have been critically studied and specimens from our own series care-

fully compared with them. I also have a large series of *A. insularis* Boheman from the Hawaiian Islands, most of which were collected by myself and four of the South American mainland species, three of the latter kindly presented by the British Museum through Dr. Blair. One of these being undescribed, will be defined in this paper. Inasmuch as many of the species are quite variable, are in fact in process of modification, certain individuals of one species often approach quite closely those of other species. These are often hard to separate but typical specimens of all good species are quite distinct.

***Ammophorus galapagoensis* G. R. Waterhouse**

Plate IV, figure 1

*Ammophorus galapagoensis* G. R. WATERHOUSE, 1845, Ann. Nat. Hist., XVI, pp. 30-31.

*Ammophorus galapagoensis* G. R. Waterhouse, C. WATERHOUSE, 1877, Proc. Zoo. Soc., V, p. 82.

*Ammophorus galapagoensis* G. R. Waterhouse, LINELL, 1898, Proc. U. S. Nat. Mus., XXI, p. 263.

*Ammophorus galapagoensis* G. R. Waterhouse, MUTCHLER, 1925, Zoologica, V, no. 20, p. 236.

Moderately small, compact, shining, nigropiceous with mouthparts and legs rufopiceous or rufous. Head with front feebly concave, finely and rather closely punctured in front, more coarsely punctured and strigose behind; antennae cylindrical, slightly wider outwards, third segment transverse. Prothorax about one-fifth wider than long, widest in front of middle, apex broadly emarginate, base feebly arcuate, sides broadly rounded, gradually narrowed behind and sinuate to well defined rectangular hind angles and abruptly sinuate in front before the prominent and feebly acute front angles; disc evenly convex, finely and rather closely punctured and more or less conspicuously rugose. Elytra twice as long as prothorax, one-fourth longer than broad, transverse at base, with prominent and acute humeral spines at outer portion of basal margin, sides abruptly sinuate behind spines but feebly arcuate at middle and gradually and evenly rounded at apex; disc moderately evenly convex, deeply and regularly sulcate, strial punctures round and shallowly impressed at bottom of sulci; the intervals narrow, carinate, prominent, feebly sinuous and with minute, sparsely placed punctures on summits. Beneath, the prothorax coarsely and sparsely punctured and opaque, the afterbody shining and coarsely and moderately closely punctured except last ventral segment which is rather finely punctured. Legs robust, fore tibiae considerably wider outwardly and with edge



regularly margined with closely placed, short setae. Length 6 mm., breadth 2.5–6 mm.

Type, collected by Charles Darwin, in the British Museum of Natural History.

***Ammophorus galapagoensis subpunctatus* Van Dyke, new subspecies**

Plate IV, figure 2

Similar to above but smaller, with the pronotal punctures fine and sparse though regularly placed, the general surface alutaceous and the median and lateral discal impressions evident though faint. Elytral striae punctures distinct but less clearly defined than in the typical species. Length 5.5 mm., breadth 2.4 mm.

*Holotype* and several paratypes from a series of nine specimens collected by F. X. Williams near **Wreck Bay, Chatham Island**, in October 1905.

***Ammophorus galapagoensis laevis* Van Dyke, new subspecies**

Plate IV, figure 3

Still smaller than the preceding subspecies, with the prothorax narrower, the pronotum smooth and shining, the surface, however, finely alutaceous and with very minute punctures. The elytra have the intervals less elevated and sharp and the striae punctures more or less obsolete. Length 5 mm., breadth 2.25 mm.

*Holotype* and six paratypes collected by F. X. Williams near **Wreck Bay, Chatham Island**, in July 1906.

The typical form of *A. galapagoensis* is represented in the collection of the California Academy of Sciences by a series of eight specimens collected near Wreck Bay, Chatham Island, in October, 1905, by F. X. Williams. These were taken in the same region as were the subspecies and many of them at the same time. Though the three forms are morphologically distinct and readily separated, there are intergrades which show that they are but variants of one species. The species as a whole is quite readily recognized by its small and compact form, shining appearance, type of pronotal punctuation, mostly fine though strigose also in typical form, elytra very transverse at base, with prominent humeral angles and shallowly impressed striae punctures as well as by having antennae that are more cylindrical than usual and with the third segment definitely transverse, a character peculiar to the species among island species and only approached by *A. costatus* among the mainland species where the segment is about as long as broad.

***Ammophorus simplex* Van Dyke, new species**

Small, compact, dull, black with mouthparts, antennae, and legs rufous. Head obscurely alutaceous, transversely impressed at fronto-elypeal union; clypeus finely, sparsely, roughly punctured, front flattened, coarsely but shallowly and moderately closely punctured; antennae almost reaching hind angles of prothorax, subcylindrical, third segment as long as broad. Prothorax about one-fifth broader than long, widest at middle, apex shallowly emarginate, base feebly arcuate, sides arcuate from apex to posterior fourth, somewhat straight at middle, suddenly narrowed and sinuate to the distinct rectangular hind angles, the front angles slightly obtuse, rounded at apices and not delimited by constrictions from apex or sides; disc feebly shining, minutely alutaceous, rather evenly convex, finely and sparsely but sharply punctured, with well marked triangular impression near base at middle, and vague lateral impressions. Elytra twice as long as prothorax and one-fourth longer than broad, subtransverse at base, humeral spines small, sides but moderately arcuate, almost parallel and evenly rounded to apex; disc somewhat flattened at middle, evenly convex at sides; striae shallowly impressed with punctures of moderate size, regular, somewhat close and deeply impressed, intervals feebly elevated, convex, not at all carinated and with sutural as prominent as rest and punctures very fine and obscure. Beneath with prothorax coarsely punctured, the abdomen rather finely and sparsely punctured and shining, the last ventral segment very finely and closely punctured. Legs robust, fore tibiae considerably expanded outwardly and with short spines irregularly placed along outer margin. Length 6.75 mm., breadth 3 mm.

*Holotype* and three paratypes, collected near **Wreck Bay, Chat-ham Island**, during January, 1906, by F. X. Williams.

This small species is one of the most distinct of the genus. It is the only one that has the striae shallowly impressed and the intervals but moderately elevated and evenly convex, not in the least degree carinate.

***Ammophorus insularis* Boheman**

Plate IV, figure 8

*Ammophorus insularis* BOHEMAN, 1858, *Fregatten Eugenies Resa*, I, p. 89.

Rather large, somewhat flattened, subopaque, black or piceous with rufous mouthparts, legs and undersurface. Head with front convex and very coarsely and deeply as well as closely punctured, clypeus finely punctured, granulate and alutaceous; antennae gradually wider outwardly, feebly compressed, and with third segment per-

ceptibly longer than broad and almost as long as the two following segments united. Prothorax one-fourth broader than long, widest at middle, apex deeply emarginate, base broadly arcuate, feebly sinuate near hind angles, sides well rounded, narrowed posteriorly and sinuate to well marked rectangular hind angles, and continuously arcuate forwards to prominent rectangular front angles; the disc somewhat flattened with a triangular impression at middle near base and shallow impressions on either side, and coarsely, closely and somewhat cribrately punctured, especially at sides. Elytra twice as long as prothorax and three-tenths longer than broad, suddenly narrowed at base, humeri well rounded and with minute spines, sides feebly arcuate, gradually rounded to apex; disc somewhat flattened, moderately sulcate, the strial punctures round, deeply and closely placed, intervals prominent, moderately carinate and with a row of small but distinct punctures along erect. Beneath shining, coarsely and closely punctured in front, less coarsely and more widely punctured behind, the last ventral segment with finer and closer punctures. Legs moderately robust, proportionally longer than in preceding species, front tibiae arcuate, gradually wider outwardly and sparsely margined on outer side with short setae. Length 8-9 mm., breadth 3.5 mm. (Boheman gives the length as 5 mm. but most specimens in a very large series from the type locality, the Hawaiian Islands, as well as specimens from Chatham Island, average much larger.)

Type, presumably in Swedish National Museum at Stockholm.

This species on the average is much the largest of the genus. Its characteristic features aside from size are the discrete type of pronotal punctuation, moderate degree of elytral sulcation with the strial punctures round and deeply impressed, the four prothoracic angles well marked and the humeral spines minute.

There is a specimen in the British Museum of Natural History from Boheman, presumably from the original type series, which I examined. I have also studied a large series from the Hawaiian Islands, considerably over a hundred, most of which I collected myself near Waikiki, Oahu, during January 1-16, 1923. The California Academy of Sciences also has a series of eighty specimens that were collected near Wreck Bay, Chatham Island in the Galapagos Islands on various dates during October 1905, and January and February 1906, by F. X. Williams. These latter specimens cannot be separated from those collected in the Hawaiian Islands. There is also a small series, five specimens, collected near Villamil and Iguana Cove, South Albemarle Island, in March, 1906, by F. X. Williams, which differ but slightly

from the preceding as for instance in having the elytra less elongate, more broadly rounded at sides and apex, with the intervals less pronounced and the hind angles of prothorax in one or two specimens somewhat acute. These I consider but slight variants, not worthy of a distinctive name, but showing a tendency towards instability. It is my belief in view of the fact that the Hawaiian colony is small, localized near Waikiki beach on the outskirts of Honolulu and near the site of the old whaling station, that the colony owes its existence to the whaling industry. It is a known fact that the whalers during the nineteenth century, perhaps earlier, frequently visited the Galapagos Islands and there secured a cargo of the giant tortoises which they used for food on their various cruises. They also, no doubt, at times shovelled some of the gravel, containing either larvae or adult beetles, from near the shore or perhaps from Wreck Bay itself on Chatham Island, into their vessels for ballast, later to be dumped overboard to make room for the casks of whale oil which were tried out on the adjacent Hawaiian mainland. The larvae and beetles readily floated to the shore and established themselves. The first specimens in Hawaii, were those taken by the collectors of the Swedish frigate *Eugenie* and described in 1858 by Boheman as from "Insula Oahu (Honolulu)." It is surprising that no specimens of the species were collected by Blackburn or Perkins and more surprising that neither listed the species in their comprehensive works dealing with the Hawaiian Coleoptera fauna seeing that it had been definitely stated to be from these islands. Its first recovery since the time of the *Eugenie*, was on April 5, 1920, when Horace Sharp of Honolulu took a number of specimens in Kaimuki and gave them to Mr. Otto Swezey who referred them to me. I had long expected that some one would find them so was not surprised. In the winter of 1923, I had the satisfaction of collecting a large series, myself, near Waikiki.

***Ammophorus blairi* Van Dyke, new species**

Rather small, dull black with piecous or rufopiecous legs. Head obscurely alutaceous, transversely impressed at fronto-elypeal union, clypeus finely granulate, front flattened, coarsely and rather closely punctured; antennae about reaching posterior fourth of prothorax, somewhat compressed, third segment at least a fifth longer than broad. Prothorax more than a fifth wider than long, widest in front of middle, apex bisinuate, distinctly arcuate at middle, base feebly and broadly arcuate, sides feebly arcuate from front angles and gradually narrowed posteriorly to hind angles, at times a bit sinuate back of front angles which are acute, prominent and extend forwards, and suddenly sinuate before hind angles which are small yet rectangular; disc dull,

obscurely alutaceous, coarsely and rather closely yet discretely punctured, feebly longitudinally impressed at middle and with well marked elliptical impressions on either side. Elytra opaque, twice as long as prothorax and one-fourth longer than broad, with humeri well rounded yet with minute spines, sides very slightly arcuate, almost straight, and well rounded at apex; disc convex, feebly flattened suturally, striae impressions moderately sulcate with coarse and round and rather closely impressed punctures, the intervals moderately and equally elevated, subearinate yet blunt at apices and finely yet distinctly and irregularly biserially punctured. Beneath coarsely punctured in front, abdomen rather finely and sparsely punctured and shining, the last ventral segment as usual very finely and closely punctured. Legs robust, front tibiae much expanded in front and outwardly margined with short spines. Length 7 mm., breadth 2.8 mm.

*Holotype*, male, allotype female, and numerous designated paratypes from a series of 100 specimens, all from **38 miles north of Olmos, Peru**, March 19, 1951 (dry thorn forest), collected by E. S. Ross and A. E. Michelbacher. The following additional specimens, all from the coastal region of northwestern Peru, have been studied: Four, 15 kilometers south of Chiclayo, March 18, 1951 (desert, old loma); forty-one, 22 miles north of Casma, March 24, 1951; two, Eten; one, Payta. The Eten and Payta specimens were loaned for study by Dr. K. G. Blair of the British Museum.

This species belongs in the series with rather coarse, discrete pronotal punctures and equally elevated elytral intervals, including besides it: *A. insularis*, *A. rubripes*, and *A. peruvianus*. It differs from the first two of these by having black or piceous legs in contrast to the rufous legs of the others; in addition from *A. insularis* by its smaller size, proportionally shorter elytra, more opaque appearance, and less acutely elevated elytral intervals; from *A. rubripes* by the coarser punctuation of both front and pronotum, a proportionally broader prothorax and much smaller humeral spine; and from *A. peruvianus* by its narrower prothorax, less pronounced pronotal punctuation, smaller hind angles to prothorax, and less elevated elytral intervals.

### ***Ammophorus antennatus* Van Dyke, new species**

Of moderate size, somewhat elongate, subopaque, dark piceous, mouthparts and legs rufous. Head coarsely, deeply, reticulately punctured, with a transverse impression separating front from clypeus, the latter finely, closely punctured; antennae very robust, subcylindrical, basal segments coarsely, rather deeply punctured, third seg-

ment as long as broad, segments 9-10 very narrow, 3 to 4 times as broad as long. Prothorax very little broader than long, widest in front of middle, apex bisinuate with median portion broadly arcuate, base also bisinuate with feeble median lobe, sides arcuate from base of front angles to base of hind angles and gradually narrowed towards base, front angles acute and prominent, projecting well forwards and but feebly constricted at base, hind angles small, acute and divergent; disc convex, rather finely yet deeply, closely and reticulately punctured, with median longitudinal, lateral and generally several shallow minor longitudinal impressions. Elytra, dull, alutaceous, almost twice as long as prothorax and one-fourth longer than broad, with rather small humeral spines, sides feebly arcuate, broadly rounded at apex; disc deeply regularly sulcate, striae punctures round, deeply impressed at bottom of sulci, intervals regular, narrow and sharply carinate, the sutural but little if at all elevated. Beneath coarsely, closely, reticulately punctured except for head and last ventral segment, the latter more finely and closely punctured. Legs as usual. Length 7 mm., breadth 3.25 mm.

*Holotype* and ten paratypes, collected on **Barrington Island**, October 1906, by F. X. Williams.

The distinctive characteristics of this species are its dull appearance, narrow prothorax, rather fine yet deep, close, reticulate type of pronotal punctuation and irregular longitudinal impressions, its robust and grossly punctured antennae and very coarsely, closely punctured frontal segments of abdomen. These peculiarities should enable it to be readily separated. The second Barrington species, placed with *A. bifurcatus* is of course widely divergent.

### ***Ammophorus cooksoni* Charles Waterhouse**

Plate IV, figure 4

*Ammophorus cooksoni* C. WATERHOUSE, 1877, Proc. Zoo. Soc. Lond., V, pp. 80, 82, fig.

*Ammophorus cooksoni* C. Waterhouse, MUEHLER, 1925, Zoologica, V, no. 20, p. 236.

*Ammophorus cooksoni* C. Waterhouse, BIVIER, 1933, Ann. Mag. Nat. Hist., ser. 10, XI, p. 478.

*Ammophorus caroli* LINEA, 1892, Proc. U. S. Nat. Mus., XXI, no. 1143, p. 264

Of moderate size, subopaque, black, with antennae, mouthparts and legs dull rufous. Head more or less flattened above, the fronto-clypeal suture obliterated and the transverse impression here very feeble; front coarsely, reticulately punctured and obscurely strigose; clypeal punctuation gradually finer; antennae about reaching pos-

terior fourth of prothorax, robust, subcylindrical, third segment slightly longer than broad. Prothorax almost a third wider than long, widest in front of middle, apex bisinuate, base almost transverse, sides gradually arcuate from apex to posterior fourth, thence sinuate and narrowed to acute, prominent and divergent hind angles, the front angles feebly acute and prominent and without basal constrictions; disc opaque, coarsely and deeply punctured and with the punctures irregular and anastomosing over much of the surface, the intervals also feebly strigose at times, the impressions feebly marked at most. Elytra almost two and a half times as long as prothorax and two-fifths longer than wide, subtransverse at base, humeral spines acute and well marked, sides almost parallel and apex well rounded; disc moderately convex, striae deeply impressed forming sulci and with punctures coarse and deep and more or less expanded into quadrilateral impressions filling the entire sulcus; the intervals well elevated, narrow, and sharply carinated, feebly sinuous, and with a few minute punctures at summits, the sutural intervals but little elevated. Beneath coarsely punctured both front and back, the abdomen shining and last ventral segment with punctures somewhat finer and closer than usual. Legs robust, fore tibiae expanded in front, outwardly margined with short setae as usual. Length (average) 8mm., breadth 3.25 mm.

The California Academy of Sciences possesses over fifty mounted specimens from Charles Island, the type locality for this species, taken during May, 1906 and October, 1905 by F. X. Williams, as well as five or six specimens labeled as from Chatham Island. Besides this series there are twenty-three specimens from the small Brattle Island, taken October, 1905, by F. X. Williams. These I place as but a weak race at the most. They are in general a bit smaller and narrower, with prothoracic and humeral angles smaller, the prothorax with the front angles somewhat constricted at their bases, the sides irregular and the disc with the lateral impressions more evident, the elytra also with the intervals more irregularly sinuous. All of the modifications seem to be the result of stunting, the race being in fact but a stunted variety.

The species, *A. cooksoni*, is very well marked, its robustness, markedly punctured and roughened pronotum, and deeply sulcate and quadrately punctured elytra enabling it to be readily recognized. Linell was not acquainted with the paper by Charles Waterhouse, hence redescribed a species which had been definitely described and figured before. This species simulates the preceding but has a broader prothorax, sharper hind prothorax angles and generally more pronounced type of sculpturing.

***Ammophorus obscurus* G. R. Waterhouse**

Plate IV, figure 5

*Ammophorus obscurus* G. R. WATERHOUSE, 1845, Ann Nat Hist., XVI, p. 32.*Ammophorus obscurus* G. R. Waterhouse, C. WATERHOUSE, 1877, Proc. Zoo. Soc. Lond., V, p. 82.*Ammophorus obscurus* G. R. Waterhouse, LINELL, 1898, Proc U. S. Nat Mus., XXI, p. 264.*Ammophorus obscurus* G. R. Waterhouse, MUTCHLER, 1925, Zoologica, V, no. 20, p. 236.*Ammophorus obscurus* G. R. Waterhouse, BLAIR, 1928, Ann Mag. Nat Hist., ser. 10, I, p. 672.

Rather small, compact, dull sericeous, black or piceous with rufo-piceous antennae, mouthparts and legs. Head flattened and coarsely, reticulately punctured, two shallow impressions at fronto-clypeal union, clypeus finely punctured; antennae subcylindrical, third segment just perceptibly longer than broad. Prothorax a fifth broader than long (in normal individuals, in abnormal individuals as in the type, almost as long as broad), widest in front of middle, apex bisinuate, base almost transverse, sides arcuate, feebly narrowed posteriorly and sinuate before front and hind angles, angles all prominent, the front acute and hind rectangular; disc coarsely and reticulately punctured, often with rugae and generally with median basal and lateral impressions. Elytra about two and a quarter times as long as prothorax and less than twice as long as wide, base subtransverse with humeral spines generally small and acute, sides feebly arcuate, broadly rounded posteriorly and almost straight and convergent to apex, disc moderately convex, deeply sulcate, the strial punctures coarse and rounded or transverse, the intervals well elevated and carinate and also irregularly sinuous, the sutural generally flat though at times distinctly elevated, the minute punctures at the summits sparse. Beneath, coarsely punctured in front, shining behind and with punctures more widely spaced, the last ventral segment with fine punctuation. Legs robust, fore tibiae dilated in front and with outer margin fringed with short setae. Length 6-7 mm., breadth 2.5-3 mm.

This species is a most variable one, some specimens being quite depauperized. The type in the British Museum is such a specimen with the prothorax narrower than normal. Specimens which I found to agree with it in all essential characters were always from Albemarle Island, therefore I believe that this island, presumably near Banks Bay where Darwin landed, is the type locality. The most variable characters are as regards the proportions, the pronotal sculpturing, the



front angles of prothorax which may have or lack the constrictions at base, and the sutural intervals which may be either flat as mentioned by Waterhouse or feebly elevated as in the more robust specimens. The California Academy of Sciences has a large series of specimens collected by F. X. Williams: 65 from Albemarle Island listed as follows, 46 from Villamil, October, 1905 and March, 1906, 5 from Iguana Cove, March, 1906, and 14 from Cowley Mountain, August, 1906. In addition there is a series of 46 specimens from Indefatigable Island, collected November, 1905, and three specimens from Duncan Island, collected December, 1905, which I place as varieties. These all have the dull sericeous appearance, the generally flattened sutural intervals, small humeral spines and more or less characteristic pronotal sculpturing of the species. The Indefatigable Island specimens generally have the pronotal sculpturing much finer, with the surface irregularly longitudinally wrinkled and the alutaceous areas more pronounced, while the Duncan Island specimens have the pronotal sculpturing more coarse than usual. The Linell citation of *A. obscurus* was questioned by Blair according to Mutchler but I am inclined to accept it for Albemarle Island is the home of that species and not *A. bifoveatus*. Eden Island (St. George Expedition) is cited on the authority of Blair

### ***Ammophorus denticollis* Boheman**

*Ammophorus denticollis* BOHEMAN, 1858, *Fregatten Eugenies Resa*, I, p. 89

This species was described by Boheman as having been collected at Panama. I am inclined to doubt this locality and for many reasons. In the first place it does not belong to the group to which the other mainland South American species do, being in fact close to several of those from the Galapagos Islands. The general distribution of the barren ground beetles of South America is as a rule more or less limited. The proven distribution of *Ammophorus* is northern Chile, Peru, and the Galapagos Islands, the Hawaiian Islands species, *A. insularis*, having been carried there through the agency of man as I have stated previously. Panama is within the moist tropics, far removed from the arid regions. *Ammophorus denticollis* Boheman has not been collected in Panama since the original was taken as far as I have learned. Other species listed from Panama by Boheman as *Pedonocces* (*Tessaromma*) *lugubris* Boheman, have since been proven to belong to the fauna of the Galapagos Islands, a proof that many of the species submitted to Boheman had wrong locality labels attached

to them. When the type of *Ammophorus denticollis* Boheman, is compared with Galapagos Island species, I believe it will be found to agree with one of the species.

***Ammophorus bifoveatus* G. R. Waterhouse**

Plate IV, figure 6

*Ammophorus bifoveatus* G. R. WATERHOUSE, 1845, Ann. Nat. Hist., XVI, pp. 31-32.

*Ammophorus bifoveatus* G. R. Waterhouse, C. WATERHOUSE, 1877, Proc. Zool. Soc., V, p. 81.

*Ammophorus bifoveatus*, G. R. Waterhouse, HOWARD, 1889, Proc. U. S. Nat. Mus., XII, no. 77, p. 192.

*Ammophorus bifoveatus* G. R. Waterhouse, MUTCHLER, 1925, Zoologica, V, no. 20, p. 236.

Rather small, dull, piceous, tarsi rufopiceous. Head coarsely, shallowly punctured, clypeus more finely punctured; antennae subcylindrical, third segment about as broad as long. Prothorax about one-fourth broader than long, widest in front of middle, apex emarginate or feebly bisinuate, base transverse, sides arcuate and narrowed from base of front angles to hind angles, front and hind angles small and acute and generally constricted at their bases; disc somewhat convex, finely but not closely punctured, with numerous irregular longitudinal rugae and faint median basal and well defined lateral impressions. Elytra two and a quarter times as long as prothorax and two-sevenths longer than broad, narrowed at base, with humeral spines acute and distinct, sides feebly arcuate, broadly rounded at apex, disc convex, deeply sulcate, punctures rounded and well impressed, without markedly transverse rugae, the intervals including the sutural are well elevated, regular and carinate. Beneath coarsely and irregularly punctured in front, abdomen shining and more sparsely and less coarsely punctured, the last abdominal segment finely punctured. Legs stout, fore tibiae but moderately dilated outwardly and finely margined with very short setae on outer margin. Length 5.5-6 mm., breadth 2.5-2.75 mm.

The type locality is James Island. The California Academy has eighty-seven specimens collected on December 25, 1905, and in January, 1906 by F. X. Williams. They show some variation in size and considerable difference in pronotal sculpturing, the punctures varying from small and sparse to moderately coarse and rather dense and the rugae may be very prominent or hardly evident. The same applies to the lateral impressions. In one small specimen, the pronotum is smooth and shining, with punctures fine and sparse though with rugae evident

and all three impressions very marked. The California Academy of Sciences also has seventy-nine specimens, taken on Charles Island in October, 1906 and on May 15, 1906 by F. X. Williams. These are a bit larger than the more typical specimens from James Island, with rufous legs, pronotal sculpturing nearer that of *A. obscurus* though with rugae yet better defined with the elytral sculpturing absolutely like that of *A. bifoveatus*, not of *A. obscurus*. These I would consider but a weak race. Besides these there are nine specimens collected on Barrington Island in October, 1905, by F. X. Williams, which seem sufficiently distinct to warrant being classed as a subspecies. This race I will define as follows:

***Ammophorus bifoveatus barringtoni*** Van Dyke, new subspecies

Larger and more generally elongate than typical members of *A. bifoveatus*; piceous, with antennae, mouthparts and legs rufous; prothorax proportionally longer, but one-fifth broader than long, with sides more feebly and irregularly arcuate, the angles more prominent, the disc more convex and the rugae more numerous and pronounced; the elytra more elongate, with sulci deep, striae punctures coarse and more transverse, the intervals more elevated and narrower though the sutural interval is but little elevated; and the underside as usual in the species. Length 7 mm., breadth 3 mm

*Holotype* and eight paratypes, collected on **Barrington Island**, in October 1905, by F. X. Williams.

This subspecies though having the forebody similar to that of *A. b. bifoveatus*, has the afterbody much more like that of *A. cooksoni*. It is no doubt not derived from either but is an offshoot from the parent stock from which both are derived, though retaining a dominance of the characters which are most characteristic of *A. bifoveatus*. For that reason, I prefer to associate it with that species rather than have it stand alone as a distinct species. From *A. antennatus* with which it has been found associated in the field, it differs widely, by being more shining, having a different type of pronotal sculpturing, smaller and more normal antennae, and by lacking the very gross and close punctuation of the forepart of the abdomen.

***Ammophorus abingdoni*** Van Dyke, new species

Plate IV, figure 7

Of moderate size, somewhat elongate, dull, piceous with antennae, mouthparts, and legs rufous. Head with coarse punctures, longitudinally rugose, without transverse impressions in front, the clypeus

finely and sparsely punctate in front, antennae slightly compressed, third segment much longer than broad, segments 8-10 hardly twice as broad as long. Prothorax about one-fifth wider than long, apex deeply emarginate, base bisinuate and with feeble lobe at middle, sides more or less irregularly sinuous, front angles prominent, acute, not constricted at base and extending well forwards, hind angles small, very acute and divergent; disc convex, coarsely punctured but with punctures anastomosing to form irregular longitudinal carinae. Elytra twice as long as prothorax, and one-third longer than broad, with small acute humeral spines, with sides almost straight or very feebly arcuate and diverging from base to posterior third, thence broadly rounded to apex; disc deeply sulcate, punctures round or somewhat transverse and well impressed, the intervals narrow and carinate and slightly sinuous, the sutural interval but feebly elevated. Beneath coarsely and closely punctured, last ventral segment finely and rather closely punctured. Legs more delicate than usual, especially the tibiae which are but little widened distally. Length 6.5 mm., breadth 2.75 mm.

*Holotype* and numerous designated paratypes from a series of sixty-nine specimens collected on **Abingdon Island**, September 18-26, 1906, by F. X. Williams

This very distinct species is readily recognized by its peculiar type of pronotal sculpturing, somewhat delicate antennae, rather long and delicate legs, and coarse punctuation of front ventral segments. In this last peculiarity, it somewhat resembles *A. antennatus* but its other characters are widely divergent.

#### KEY TO SPECIES OF GENUS *AMMOPHORUS* GÜERIN-MENEVILLE

- |    |   |  |
|----|---|--|
| 1  | Third antennal segment transverse, evidently broader than long  | 2  |
| -- | Third antennal segment longer than broad  | 3  |
| 2  | Pronotum varying from finely punctate and finely strigose to more or less smooth and alutaceous with fine or minute punctures, elytral intervals equally elevated | <i>A. galapagoensis</i> G. R. Waterhouse |
| -- | Pronotum irregularly punctured, more dense at front and back and sides; elytral intervals alternately elevated, strial punctures large                            | Peru ..                                  |
|    |   | <i>A. costatus</i> Güérin-Meneville      |
| 3. | Pronotum discretely punctured, punctures anastomosing to a slight degree at most  | 4  |
| —  | Pronotum coarsely punctured, rugose, striate or with punctures more or less irregularly anastomosing  | 9  |
| 4. | Elytral intervals alternately elevated, strial punctures small or obsolete,   |  |

- intervals finely granulate, humeral spine prominent; general appearance somewhat shining, legs rufous. Peru. .... *A. spinotae* Solier
- Elytral intervals equally elevated ..... 5
5. Pronotum more or less coarsely, closely punctured; elytra with intervals well elevated, subcarinate and rather finely yet distinctly punctured . 6
- Pronotum quite small and alutaceous with punctures fine and widely spaced; elytra with intervals more or less convex but feebly elevated; the fine punctures obsolete ..... *A. simplex*, new species
6. Smaller species, 7 mm. or less in length, hind angles of prothorax small; elytral intervals blunt at apices, sutural intervals flat . . . . . 7
- Larger species, 8 mm. or more in length, hind angles of prothorax rectangular and rather distinct; elytra with small humeral spine, distinctly elevated sutural interval and with others prominent and subcarinate ..... *A. insularis* Boheman
7. Body black or piceous, legs rufous ..... 8
- Entire body including legs black or piceous, frontal punctures coarser than pronotal; elytra quite rounded at base, humeral spine, intervals moderately subcarinate, striae punctures shallowly impressed Peru ..... *A. blairi*, new species
8. Pronotum but little wider than long, moderately and shallowly punctured, posterior angles small; elytra only moderately sulcate, the intervals quite convex, the striae and striae punctures sharply impressed, punctures of occiput and pronotum quite similar Peru *A. rubripes* Solier
- Prothorax definitely transverse, densely punctured, hind angles prominent; elytra profoundly sulcate, and with striae punctures well impressed, the intervals distinctly elevated and very finely punctured ..... *A. peruvianus* Guérin-Ménéville
9. Pronotum rugose-reticulate and deeply punctured, not striate; striae punctures of elytra large, more or less irregular and generally transverse ..... 10
- Pronotum more or less striate and with longitudinal rugae and finely or somewhat coarsely punctured ..... 12
10. Prothorax almost as long as broad, pronotum rather finely yet deeply, closely and reticulately punctured and with numerous irregular longitudinal impressions, antennae very robust, the basal segments very coarsely, deeply punctured, segments 9-10 very short and transverse, three to four times as broad as long, elytra dull black, alutaceous ..... *A. antennatus*, new species
- Prothorax strongly transverse, with longitudinal impression at middle of pronotum, otherwise evenly transversely convex; antennae not more robust than usual, basal segments shallowly or more finely punctured, segments 9-10 less narrow, not three times as broad as long . 11
11. Head and pronotum very coarsely punctured, punctures more or less anastomosing, and reticulate, front angles rectangular, prominent, generally not constricted at base, hind angles small; elytral punctures very gross and transverse strigae separating them somewhat carinate, humeral spines small; legs bright rufous ..... *A. cooksoni* C. Waterhouse

- Head and pronotum but moderately coarsely punctured, punctures close, somewhat anastomosing and reticulate, front angles acute, constricted at base, hind angles small and acute; elytra dull and alutaceous, striae punctures more shallowly impressed and with the transverse rugae separating them less elevated and not carinate, humeral spines very small; legs piceous or rufopiceous..... *A. obscurus* G. R. Waterhouse
- 12. Pronotum coarsely, rugosely punctured, longitudinally striate, all angles small and acute; elytra profoundly punctured, humeral spines small; legs black, tarsi piceous. Panama ..... *A. denticollis* Boheman
- Head and pronotum more finely punctured and with longitudinal rugae, hind angles of prothorax acute . . . . . 13
- 13. Prothorax much broader than long, pronotum rather finely, not densely punctured and with irregular longitudinal rugae; elytra transverse at base and with intervals quite straight.....*A. bifoveatus* G. R. Waterhouse
- Prothorax almost as long as broad, pronotum with obscure punctures but with coarse, irregular, longitudinal rugae; elytra somewhat elliptical, narrowed and rounded towards base, intervals sinuous.....  
.....*A. abingdoni*, new species

### Genus *Pedonoecus* G. R. Waterhouse

*Pedonoecus* G. R. WATERHOUSE, 1845, Ann. Nat. Hist., XVI, pp. 32-35.

*Tessaromma* BOHEMAN, 1858, Fregatten Eugenes Resa, I, p. 91.

Like the genus *Stomion* which was also proposed by G. R. Waterhouse, the genus *Pedonoecus* is confined in the distribution of its species to the Galapagos Islands.

Though many of the species of *Pedonoecus* are quite distinct, the genus as a whole is a very weak one. As indicated by Waterhouse, the main difference between it and *Blapstinus* is the fact that its members are wingless and the elytra soldered together. The more highly specialized species such as were studied by Waterhouse are of course absolutely without wings but some of the more generalized ones such as have been collected in recent times have fairly large though functionless wings. Many species of *Blapstinus* are also flightless and many have only the merest rudiments of wings. The two genera thus grade one into the other, proving that *Pedonoecus* is little more than a subgenus of the more widely spread *Blapstinus*. For convenience, I will treat *Pedonoecus* as a distinct unit and include all of the Galapagos Pediniinae in it, leaving the settlement of its generic status until such times as the tribe can be reviewed as a whole. In the Galapagos Islands, the species vary from such generalized forms as *P. wernmani* which have rudimentary wings, and cannot be satisfactorily separated from mainland species of *Blapstinus*, to such highly specialized forms as

*P. lugubris* which look very unlike any of the more typical forms of *Blapstinus*.

The genus *Blapstinus* is a large one found throughout North America, the West Indies, and western and southern South America. It is very richly developed in the southwestern part of the United States, particularly California, and may be equally well developed in western South America. In the Galapagos Islands, there are three well marked groups of *Pedonoeces*: the "*pubescens*" group, the "*galapagoensis*" group, and the "*lugubris*" group. The members of the first group are what I called generalized species, such species as have rudimentary wings and are in appearance but little different from typical forms of *Blapstinus*. The members of this group are *P. wenmani*, *P. culpepperi*, *P. pubescens*, *P. blairi*, *P. caudatus*, and *P. uniformis* and are to be found in the most northern islands as well as the more southern ones. A boundary line drawn to encompass them would, as indicated in the map, take in all islands of the north, east and south, the outer boundary group. No species of *Pedonoeces* have been taken on Abingdon, Bindloe, or Tower islands but if any such are ever taken I believe they will belong to this group. The "*galapagoensis*" group includes *P. bauri*, *P. galapagoensis*, *P. morio*, *P. duncani*, *P. costatus*, and *P. williamsi*. They are to be found on the innermost group of islands: James, Indefatigable, Duncan, and Charles. If the species, *P. spatulatus* and *P. barrington*, which are somewhat divergent, be included, Barrington and Hood islands would have to be listed. The most highly specialized "*lugubris*" group includes *P. lugubris*, *P. opacus*, and *P. nigrinus*. Its distribution is more transverse, centralized in Indefatigable Island but also represented to the west in Jervis, South Albemarle, and Hood islands. The species *P. duncani*, which I have included in the preceding group on account of the evident stria punctures, might almost equally well be placed in the "*lugubris*" group, thus would properly round out the distribution. A study of the distribution shows that it is not haphazard but orderly and in line with what one would expect as the primitive Galapagos land mass was broken up into the present group of islands.

***Pedonoeces wenmani* Van Dyke, new species**

Plate V, figure 1

Small, elliptical, rufopiceous, upper surface moderately and evenly convex and sparsely clothed with golden pubescence. Head moderately and deeply punctured, clypeus shallowly emarginate; antennae not reaching hind angles of prothorax, third segment not equal

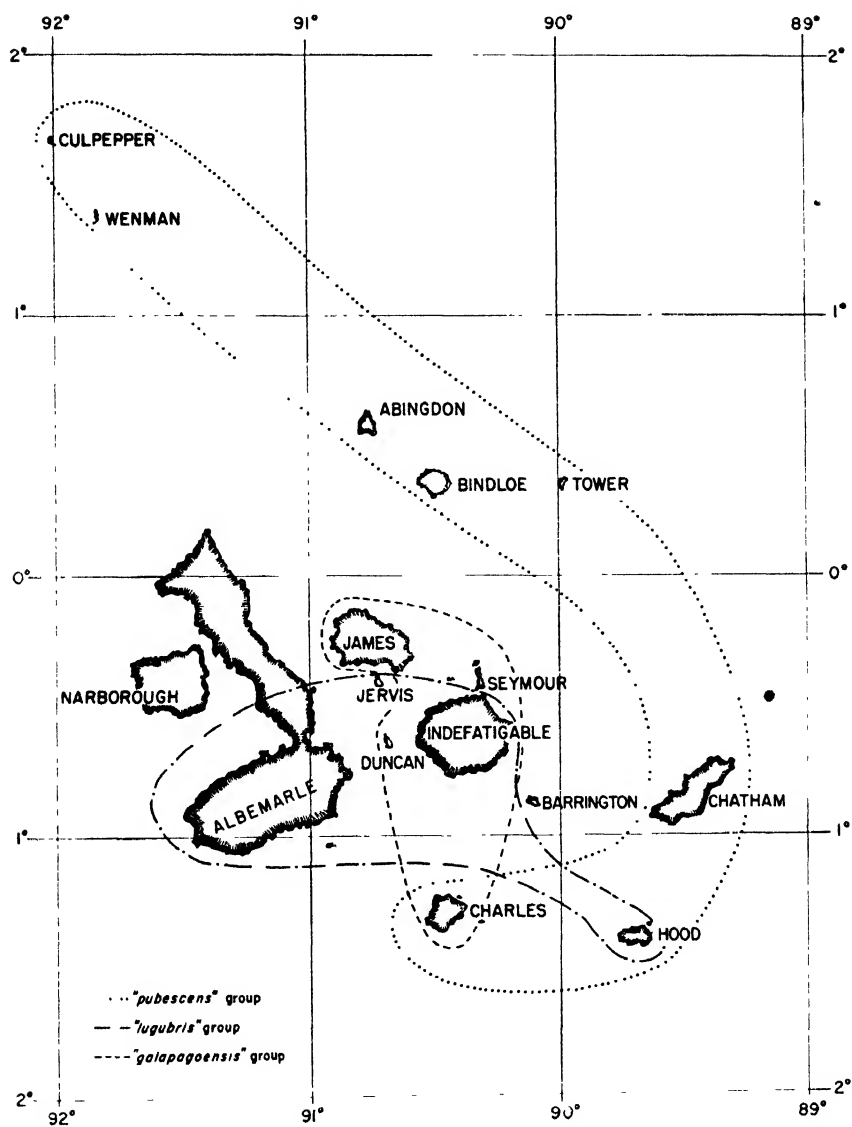


FIGURE 1

Map of the Galapagos Islands, showing the distribution of the three groups of species of the genus *Pedonocces*.



to fourth and fifth combined, outer segments gradually clavate, 8-10 transverse. Prothorax more than one-fourth broader than long, apex feebly and base strongly bisinuate, sides almost straight and parallel in basal half, evenly rounded to apex in front; disc densely punctured with a faint indication of longitudinal striation in some specimens. Scutellum faintly punctured. Elytra two-sevenths longer than broad and about three times as long as prothorax, sides parallel for basal two-thirds, thence gradually rounded to apex; disc with striae finely yet sharply impressed and with small and somewhat close strial punctures, intervals flat and irregularly punctured, the punctures almost as large as those of striae. Beneath coarsely and closely punctured in front, more finely and discretely so behind. Males with but slight flattening of abdomen and more widely dilated front tarsi, otherwise not different from females. Length 4.5-5 mm., breadth 2.25 mm., wings present but rudimentary.

*Holotype* and numerous designated paratypes from a series of fifty-eight specimens collected September 24, 1905, on **Wenman Island**, by F. X. Williams.

This species is one of the most generalized of the genus and hardly distinguishable from the smaller species of *Blapstinus*. It is but little larger than the next which is the smallest in the islands.

### ***Pedonoeces culpepperi* Van Dyke, new species**

Similar to preceding but smaller, lighter in color, somewhat more evidently pilose, antennae less robust, the tenth segment alone transverse, the elytral striae broader and strial punctures coarser and the punctures of intervals much smaller than those of striae. Length 4.5 mm., breadth 2 mm., wing two-thirds of normal length.

*Holotype* and four paratypes, collected on **Culpepper Island**, October 25, 1905.

This is our smallest species, very close to the preceding yet definitely distinct.

### ***Pedonoeces pubescens* G. R. Waterhouse**

Plate V, figure 7

*Pedonoeces pubescens* G. R. WATERHOUSE, 1845, ANN. NAT. HIST., XVI, p. 36.

*Pedonoeces pubescens* G. R. Waterhouse, C. WATERHOUSE, 1877, PROC. ZOO. SOC. LOND., V, p. 82.

*Pedonoeces pubescens* G. R. Waterhouse, LINELL, 1898, PROC. U. S. NAT. MUS., XXI, p. 266

*Pedonoeces pubescens* G. R. Waterhouse, Mutchleb, 1925, Zoologica, V, no. 20, p. 236.

*Pedonoeces pubescens* G. R. Waterhouse, Blair, 1933, Ann. Mag. Nat. Hist., ser. 10, XI, p. 479.

Rather small, elliptical rufopiceous, dorsal surface evenly convex, finely alutaceous and sparsely clothed with fine golden pile, sometimes vittate on elytra. Head finely and sparsely punctured, clypeus semicircularly emarginate in front; antennae not reaching hind margin of prothorax; third segment considerably shorter than fourth and fifth combined, outer segments gradually clavate, tenth transverse. Prothorax over one-fourth broader than long, apex emarginate, base transverse, sides evenly arcuate, disc finely and sparsely punctured. Scutellum minutely punctured at apex. Elytra over one-third longer than broad and almost three times as long as prothorax, sides feebly arcuate in basal two-thirds and evenly rounded to apex; disc with striae finely impressed and strial punctures rather coarse and closely placed, the intervals feebly but evidently convex especially at sides and minutely as well as somewhat obscurely punctured. Beneath obscurely rugose in front, rather finely and sparsely punctured behind. Males with front ventral segments somewhat concave but not showing distinctive femoral or tibial characters. Length 5 mm., breadth 2.5 mm.

Type locality Chatham Island. The California Academy of Sciences has five specimens from this island, one of which was carefully checked with the type. They were collected October 14, 1905 and January, 1906, by F. N. Williams. This species is slightly larger than either of the preceding species, with much finer pronotal punctures and deeper elytral striae.

### ***Pedonoeces blairi* Van Dyke, new species**

Moderate sized, elongate, rufopiceous, disc somewhat flattened and clothed with very short pile, semierect on elytra. Head densely and rather coarsely punctured, transversely impressed in front of eyes, clypeus angulately emarginate; antennae reaching posterior third of prothorax, third segment elongate but shorter than two following united, gradually clavate from fifth segment, the tenth transverse. Prothorax two-ninths broader than long, apex broadly and deeply emarginate, base bisinuate, sides almost straight and feebly divergent from base to well beyond middle, thence rounded to apex; disc rather coarsely and densely punctured. Scutellum finely punctured. Elytra three-eighths longer than broad and about two and a half

times as long as prothorax, sides very feebly arcuate and convergent to apex; disc with striae well impressed, finely and closely punctured, intervals convex and irregularly punctured with minute punctures. Beneath coarsely and longitudinally rugose in front and rather coarsely punctured behind. Males with front ventral segments concave at middle but without peculiar femora or tibiae. Length 6–6.5 mm., breadth 2.25–2.50 mm.

*Holotype* and numerous designated paratypes from a series of sixty-three specimens, collected on **Charles Island**, October 3, 1905, by F. X. Williams.

The species is slightly larger and much more elongate than *P. pubescens*, with head and pronotal punctures coarser and denser, elytral striae deeper, intervals convex and pile of elytra semierect but not noticed except under magnification.

### ***Pedonoecus caudatus* Van Dyke, new species**

Plate V, figure 2

Narrow, elongate, rufopiceous, disc somewhat depressed and sparsely clothed with short and fulvous pile, obliquely inclined on elytra. Head moderately finely punctured, punctures well spaced and finer in front, a transverse impression in front of eyes, clypeus broadly and shallowly emarginate, antennae almost reaching hind margin of prothorax, third segment slightly shorter than two following united, gradually clavate from seventh segment and all longer than broad. Prothorax one-third broader than long, apex broadly emarginate, base bisinuate, sides more or less straight and parallel to apical third, thence arcuate and narrowed to apex; disc rather coarsely, densely punctured. Scutellum finely punctured. Elytra almost twice as long as broad and about three times as long as prothorax, sides evenly arcuate from base to narrowed and prolonged apex in female, disc as in *P. blairi* except that pile is more inclined. Beneath somewhat rugose in front and rather finely punctured behind. Males with front ventral segments flattened and with dense patches of erect silky pile at middle of front and middle thighs behind. Front and middle tarsi also more dilated than usual. Length 6–7 mm., breadth 2–3 mm.

*Holotype* male, allotype female and numerous designated paratypes from a series of twenty-two specimens, collected on **Hood Island**, September 24–30, 1905 and February 1–14, 1906.

Superficially this species looks much like a large, more elongate, and in the female caudate specimen of the preceding species. It, how-

ever, has several positive characters of its own such as a different type of clypeal emargination, broader and more parallel-sided prothorax, and strikingly different sexual characters. There is considerable variation in size and shape, the females having the apex of the elytra not only prolonged but somewhat narrowed as well. It is wingless.

***Pedonoeces apicalis* Van Dyke, new species**

Somewhat similar in size and general appearance to the preceding species, *P. caudatus*, but duller, the prothorax somewhat broader, two-fifths broader than long, the pronotum more finely and densely punctured, the punctures approximate over much of the area, the general surface alutaceous, the lateral margins very narrow, much less conspicuous than in the other species; the elytra with the striae more finely and shallowly punctured and the intervals with the punctures less sharply defined. Length 7 mm., breadth 3 mm.

*Holotype*, a unique female, slightly immature, rufous in color instead of piceous, collected on **Tower Island**, September 14, 1905, by F. X. Williams. This female specimen has the apex of the elytra slightly extended and the sutural intervals conspicuously elevated at the sutural angle as in the females of *P. caudatus*, and divergent. It is most readily separated from *P. caudatus* by the broader prothorax, more densely punctured pronotum, and more finely margined sides of pronotum.

***Pedonoeces uniformis* Van Dyke, new species**

Of moderate size, elongate, elliptical, rufopiceous, and finely and sparsely pubescent, the pile very short and semierect on elytra. Head rather densely punctured, a transverse impression in front of the eyes, clypeus triangularly emarginate; antennae not reaching hind margin of prothorax, third segment about three-fourths length of two following united, gradually clavate from sixth segment, tenth transverse. Prothorax one-fourth broader than long, apex broadly emarginate, base bisinuate, sides feebly arcuate, slightly narrowed in front, disc rather coarsely, densely punctured. Scutellum finely punctured. Elytra two-sevenths longer than broad and almost two and a half times as long as prothorax, widest behind the middle, sides feebly arcuate and gradually narrowed and rounded to apex; disc with striae sharply and deeply impressed and coarsely as well as closely and crenulately punctured. Beneath coarsely and rugosely punctured in front, somewhat coarsely and densely punctured behind. Length 5 mm., breadth 2.25 mm.

*Holotype*, a unique collected near **Wreck Bay, Chatham Island**, in October 1906, by F. X. Williams.

This species is somewhat similar and suggestive of *P. blairi* but it has a narrower prothorax and coarser pronotal punctures, the elytral striae more deeply and somewhat more widely and very much more coarsely punctured, and the intervals more narrowly and distinctly elevated. It is in a way a species intermediate between the members of the "*pubescens*" group and those of the "*galapagoensis*" group.

### ***Pedonoeces bauri* Linell**

Plate V, figure 3

*Pedonoeces bauri* LINELL, 1898, Proc. U. S. Nat. Mus., XXI, p. 265.

*Pedonoeces bauri* Linell, MUTCHLER, 1925, Zoologica, V, no. 20, p. 237.

Rather large, elongate, elliptical, rufopiceous, alutaceous, glabrous except for a few short hairs above eyes and at sides and apex of elytra. Head finely, somewhat sparsely punctured, clypeus emarginate at middle; antennae rather slender, not reaching hind margin of prothorax, third segment almost one-fourth shorter than the two following united, gradually clavate from sixth segment with tenth alone transverse. Prothorax almost one-third broader than long, apex broadly emarginate, base bisinuate, sides feebly arcuate behind, more rounded and narrowed towards apex, disc convex yet somewhat flattened at middle, finely and quite distantly punctured. Scutellum minutely punctured near hind margin. Elytra two-fifths longer than wide and less than twice as long as prothorax, sides very feebly arcuate to posterior third thence more rounded and narrowed to apex; disc convex, but somewhat depressed near suture, striae deeply and broadly impressed and rather coarsely but not closely punctured; intervals convex and well elevated, especially on declivity, and minutely, sparsely punctured. Beneath rugose in front, finely and sparsely punctured behind. Males differing only by having front ventral segments concave and fore tarsi dilated as usual. Length 6-8 mm., width 2.5-3.25 mm.

The type locality is Chatham Island. The California Academy of Sciences has seventy-six specimens, collected in October, 1905, by F. X. Williams. They show considerable variation in size, proportionate length, in size of strial punctures and degree of elevation of intervals, particularly on declivity.

This species is the first of the robust group and is characterized in particular by the rather broad strial impressions of the elytra, coarse punctures, and well elevated convex intervals. Its closest ally is *P. galapagoensis* which has a proportionally longer, narrower prothorax

with sides sinuate basally, somewhat coarser and deeper discal punctures and more shining surface. Its elytra are also more spatulate, with more sulcate and more coarsely punctured striae and narrow and somewhat costate intervals as well as more coarsely punctured ventral segments and definite male sexual differences.

***Pedonoecus galapagoensis*** (G. R. Waterhouse

Plate V, figure 4

*Pedonoecus galapagoensis* G. R. WATERHOUSE, 1845, Ann. Nat. Hist., XVI, p. 35.

*Pedonoecus galapagoensis* G. R. Waterhouse, C. WATERHOUSE, 1877, Proc. Zoo. Soc. Lond., V, p. 82.

*Pedonoecus galapagocnsis* G. R. Waterhouse, LINELL, 1898, U. S. Nat. Mus., XXI, p. 265.

*Pedonoecus galapagoensis* G. R. Waterhouse, MITCHLER, 1925, Zoologica, V, no. 20, p. 236.

*Pedonoecus galapagoensis* G. R. Waterhouse, BLAIR, 1933, Ann. Mag. Nat. Hist., ser. 10, XI, p. 479.

Somewhat elongate, robust, rufopiceous, more or less glabrous and shining. Head rather coarsely and somewhat irregularly and densely punctured, transverse impression in front of eyes, clypeus emarginate; antennae not reaching hind margin of prothorax, third segment as long as two following united, clavate from eighth segment and with tenth definitely transverse. Prothorax over one-fifth broader than long, widest in front of middle, apex broadly emarginate, base bisinuate, sides sinuate near base, arcuate forwards to beyond middle thence rounded and narrowed to apex, hind angles rectangular and with fovea at inner side; disc convex, densely and somewhat coarsely punctured, punctures often elongate. Scutellum finely punctured. Elytra spatulate, about one-fourth longer than broad and over twice as long as prothorax, sides arcuate, gradually wider to posterior third, thence evenly rounded to apex; disc convex, striae broadly and deeply impressed and both coarsely and more or less closely punctured, intervals narrow; well elevated and somewhat costate, especially posteriorly, also more or less alternately unequally elevated on declivity, and minutely punctured. Beneath coarsely rugose in front and rather coarsely, somewhat closely punctured behind. Males with anterior ventral segments slightly concave, a deep circular impression on last ventral segment, and patches of erect and golden pile on inner face of all femora in addition to the usual dilated tarsi. Length 7 mm., breadth 3.25 mm.

Type locality James Island. The California Academy of Sciences has eight specimens collected there, January 1-4, 1906, by F. X. Wil-

liams. This species is, as has been stated, most closely related to *P. bauri* but readily separated by the characters given. The only other species that might be compared with it are *P. costatus* and *P. morio*. *Pedonoeces costatus* has the pronotum striate as the result of longitudinal anastomosing of coarse, close punctures and the elytra, though spatulate, with the intervals unequally elevated throughout the carinate. It also is from James Island. *Pedonoeces morio* from Indefatigable Island is more convex, blacker, subopaque, with the elytral sulci more angulately impressed and the punctures somewhat obsolete, and the intervals decidedly carinate.

***Pedonoeces spatulatus* Van Dyke, new species**

Plate V, figure 5

Narrow, elongate, flattened, rufopiceous, sparsely clothed with minute and closely appressed pile. Head coarsely and densely punctured, transverse impression in front of eyes, clypeus moderately emarginate; antennae almost reaching hind margins of prothorax, third segment about as long as two following united, clavate from eighth segment, tenth segment transverse. Prothorax about one-fourth broader than long, apex broadly emarginate, base trisinate, sides almost straight and parallel in basal half, arcuate and gradually narrowed to apex; disc feebly convex, coarsely and densely punctured, hind angles acute. Scutellum finely punctured. Elytra spatulate, widest behind middle, three-eighths longer than broad and over twice as long as prothorax, sides feebly arcuate and gradually wider until behind middle thence convergent to rather acute and produced apex, disc with striae well impressed, finely and closely punctured, intervals wider than striae, the odd more elevated than the even and somewhat more evidently though obtusely carinate and all minutely punctured. Beneath coarsely punctured and rugose in front and finely and sparsely punctured behind. Males with anterior sternites shallowly concave and last ventral segment broadly impressed and with a posterior semicircular carina, the front tarsi dilated as usual. Length 6 mm., breadth 2.5 mm.

*Holotype*, allotype, and seven paratypes collected on **Hood Island**, February 1 and 4, 1906, by F. X. Williams. With this species, I have associated a single specimen from Gardner Island near Hood, collected in October 1905, by F. X. Williams.

This flat species is in general facies more like *P. caudatus* and should really follow it except for the fact that the elytral intervals are somewhat carinate; they are also more irregularly elevated. It is quite a distinct species.

**Pedonoeces barringtoni** Van Dyke, new species

Plate V, figure 9

Elongate, parallel sided, more or less flattened, coarsely sculptured, subopaque; rufopiceous, with antennae, mouthparts, and legs rufous. Head coarsely and also closely and reticulately punctured, transverse impression in front of eyes, clypeus shallowly emarginate, antennae extending to posterior third of prothorax, third segment almost equal in length to the two following united, gradually clavate from the ninth segment and without any transverse segments. Prothorax one-fourth broader than long, apex emarginate, base bisinuate, sides almost parallel posteriorly and rounded to apex; disc coarsely, closely, reticulately punctured. Scutellum finely, closely punctured. Elytra twice as long as broad and almost three times as long as prothorax, sides almost straight and feebly narrowing to posterior third thence arcuate and convergent to apex, disc with striae broadly impressed and with flat bottoms in which the punctures are coarsely, closely, and shallowly impressed, the intervals narrow, about one-third width of striae and acutely carinate. Beneath coarsely and shallowly punctured in front, less coarsely but equally shallowly punctured behind and dull and rugose. Front ventral segments concave at middle and last ventral segment broadly impressed. Length 5 mm., breadth 2.25 mm.

*Holotype*, a unique male, collected on **Barrington Island**, October 19-24, 1905.

This very distinct species, should in a way follow the members of the "*pubescens*" group but the coarse sculpturing and acutely carinate elytral intervals in spite of its flatness and parallel form throw it nearer the members of the "*lugubris*" group.

**Pedonoeces morio** (Boheman)

*Tessaromma morio* BOHEMAN, 1858, Fregatten Eugenies Resa, I, p. 92

*Pedonoeces morio* (Boheman), C. WATERHOUSE, 1877, Proc. Zoo. Soc., V, p. 82

*Pedonoeces morio* (Boheman), LINEI, 1898, Proc. U. S. Nat. Mus., XXI, p. 265

*Pedonoeces morio* (Boheman), MITCHLER, 1925, Zoologica, V, no. 20, p. 237.

*Pedonoeces morio* (Boheman), BLAIR, 1933, Ann. Mag. Nat. Hist., ser. 10, XI, p. 479.

Moderate size, robust, black or dark piceous, convex, glabrous above, Head finely and rather sparsely punctured, transverse impression in front of eyes, clypeus acutely emarginate, antennae almost reaching hind margin of prothorax, third segment shorter than two



following united, clavate from seventh segment, tenth segment transverse. Prothorax almost two-fifths broader than long, apex broadly emarginate, base bisinuate, sides straight and parallel for basal half, convergent and feebly arcuate to apex, hind angles subacute and slightly extended backwards; disc very convex, finely and rather densely punctured and with head markedly alutaceous and opaque. Scutellum finely, sparsely punctured. Elytra very convex, alutaceous, two-fifths longer than broad and over two and a half times as long as prothorax, sides feebly arcuate, more rounded and convergent to apex; disc deeply and acutely sulcate, with fine yet evident and well spaced punctures, intervals broad, carinate and with summits finely punctured. Beneath, coarsely and shallowly punctured in front, rather coarsely and discretely punctured behind and longitudinally rugose. Males with front ventral segments concave, last ventral segment flattened apically and a small sparse patch of yellow pile on undersurface of middle and hind femora. Length 7 mm., breadth 3 mm.

Boheman gives no particular island for his specimens. Blair lists one from James Island. The specimens in the California Academy of Sciences Collection which fit the description are five specimens from Indefatigable Island, collected May 5, 1932, by M. Willows, Jr., of the Templeton Crocker Expedition. These vary somewhat in size, most being a bit larger than the length given by Boheman,  $5\frac{1}{2}$  mm.

This opaque species with distinctly sulcate elytra, punctured striae and carinate intervals should be confused with no others. In *P. costatus*, the pronotum is coarsely sculptured, with somewhat strigose punctures, and elytral intervals unequally elevated. In *P. lugubris* and those species which are associated with it, the elytral sulci are impunctate.

### ***Pedonoeces batesoni* Blair**

*Pedonoeces batesoni* BLAIR, 1933, Ann. Mag. Nat. Hist., ser. 10, XI, p. 479.

I have no specimens of this species before me.

### ***Pedonoeces duncani* Van Dyke, new species**

Very similar to *P. morio* in shape and general appearance but somewhat more elongate and less convex. Head coarsely and densely yet shallowly punctured and rugose, transverse impression in front of eyes vague, clypeal emargination acute. Prothorax two-fifths broader than long, apex broadly and somewhat shallowly emarginate, base markedly

bisinate, sides straight and feebly divergent from base to beyond middle and thence arcuate and narrowed to apex; disc coarsely, closely punctured with most punctures longitudinally anastomosing producing an irregular striate appearance. Elytra three-eighths longer than broad, acutely sulcate with strial punctures fine but well impressed and close, the intervals of equal width to sulci and raised and carinate. Beneath coarsely punctate and rugose in front, more distinctly and discretely punctured behind.

*Holotype*, a mature piceous specimen, 6 mm. long and 2.5 mm. wide, probably a male, a paratype of the same size but immature and two larger mature specimens, 7 mm. long by 3 mm. wide, presumably females, collected on **Duncan Island**, the first two August 14, 1906, and the others December 1-17, 1905, by F. X. Williams.

This species belongs near *P. morio* as shown by its general appearance and elytral sculpturing but its more flattened upper surface and grossly punctured head and pronotum readily separate it.

### ***Pedonoecus costatus* G. R. Waterhouse**

Plate V, figure 6

*Pedonoecus costatus* G. R. WATERHOUSE, 1845, Ann. Nat. Hist., XVI, p. 35.

*Pedonoecus costatus* G. R. Waterhouse, LINELL, 1898, Proc. U. S. Nat. Mus., XXI, p. 265.

*Pedonoecus costatus* G. R. Waterhouse, MUTCHLER, 1925, Zoologica, V, no. 20, p. 237.

*Pedonoecus costatus* G. R. Waterhouse, BLAIR, 1933, Ann. Mag. Nat. Hist., ser. 10, XI, p. 479

Moderate in size, robust, black or piceous with antennae, mouthparts and legs rufous, quite convex above, and glabrous. Head coarsely and closely punctured, more finely so in front and behind, alutaceous, transversely impressed in front of eyes, clypeus broadly emarginate; antennae about reaching posterior third of prothorax, third segment fully as long as two following united, clavate from eighth segment, ninth and tenth segments transverse. Prothorax about one-fifth broader than long, quite convex, apex broadly emarginate, base bisinate, sides feebly arcuate from base to middle thence more gradually rounded and narrowed to apex, hind angles broad and acute and projecting backwards; disc irregularly longitudinally striate and punctate. Scutellum finely punctured. Elytra over one-fourth longer than broad, and fully twice as long as prothorax, somewhat spatulate in shape, humeri rounded, sides arcuate and well rounded to apex; disc very convex, sulci broad and deep, the strial punctures well rounded as well as well spaced

and well impressed, intervals narrowly carinate, the third, fifth, and seventh considerably more elevated than others, general surface alutaceous. Beneath coarsely and densely punctured in front, more sparsely and more finely so towards apex of abdomen, and entire abdomen quite alutaceous. Males with front ventral segments broadly concave, the last ventral segment broadly excavated, the second and third femora with dense patches of yellow pile beneath and the first less distinctly pubescent. The females with last ventral segment deeply impressed. Lengths 6-7 mm., breadth 2.5-3 mm.

James Island is the type locality. The California Academy of Sciences has numerous specimens from there, all collected by F. X. Williams on January 1-4, 1906. It is a well defined species because of its striate pronotum and elytra with alternately elevated costae and well defined strial punctures. It is only closely approached by the next species.

***Pedonoeces williamsi* Van Dyke, new species**

Of moderate size, elliptical, robust, rufous (probably immature), very convex above and glabrous. Head very coarsely and closely and also cribrately punctured, transversely impressed in front of eyes, clypeus bilobed in front; antennae extending well back of middle of prothorax, third segment as long as two following united, gradually clavate outwards, ninth and tenth segments transverse. Prothorax fully two-fifths broader than long, apex broadly emarginate, base broadly lobed at middle, sides almost straight and feebly diverging from base to middle and thence arcuate and gradually narrowed towards apex, hind angles almost rectangular, disc very convex, feebly longitudinally impressed at middle with well marked fovea in front of scutellum and coarsely as well as closely and cribrately punctured with tendency of punctures near middle to longitudinally anastomose. Scutellum with a few obscure punctures. Elytra one-fourth longer than broad and over twice as long as prothorax, sides feebly arcuate from base to posterior third, thence more rounded and rapidly narrowing to apex; disc very convex, sulci broad and deep, the strial punctures rather close and round and moderately impressed, intervals narrowly costate with the third and fifth and seventh somewhat more elevated than the others, the general surface shining yet with sulci alutaceous. Beneath very coarsely and umbilicately punctured in front and rather coarsely and somewhat closely punctured behind and smooth and shining. Length 6 mm., breadth 2.5 mm.

*Holotype*, a unique collected on **Indefatigable Island**, October 25-28, 1905, by F. X. Williams.

This species somewhat resembles the preceding but its elliptical shape, very coarse punctuation on the upper surface and beneath and the sharp carinae of all intervals should separate it. The specimen appears to be slightly immature to judge from the color.

***Pedonoeces lugubris* (Boheman)**

Plate V, figure 8

*Tessaromma lugubris* BOHEMAN, 1858, Fregatten Eugenies Resa, I, p. 91. Tafl. 1, fig. 5.

*Pedonoeces lugubris* Boheman, BLAIR, 1933, Ann. Mag. Nat. Hist., ser. 10, XI, pp. 479-480.

Large to moderate size, robust, somewhat elongate, dull black, with depressed and minute hair scattered over the head and prothorax and to a lesser extent the elytra; antennae rufous and legs rufopiceous. Head alutaceous, rather finely and discretely punctured, transversely impressed in front of eyes, clypeus broadly emarginate in front; antennae extending beyond middle of prothorax, third segment as long as two following united, four other segments gradually enlarged to form a loose club with the eighth and ninth segments triangular and the tenth and eleventh segments transverse. Prothorax a little less than one-third broader than long, apex broadly emarginate with anterior angles obtusely projecting, base bisinuate with broad median lobe, hind angles acute and moderately projecting backwards, sides broadly and evenly arcuate from base to apex, feebly narrowed to front; disc moderately convex, very feebly longitudinally impressed at middle, alutaceous and finely punctured. Elytra somewhat spatulate, almost two-fifths longer than broad, twice as long as prothorax and distinctly narrower at base than base of prothorax, sides feebly arcuate, gradually wider to beyond middle thence evenly rounded to apices, disc convex though somewhat flattened medially, sulci broad and deep, the striae punctures sparse and fine and also obscure, intervals narrowly carinate and equally elevated, and more or less evidently punctured at apices with minute punctures, the general surface dull and alutaceous as are the head and pronotum. Beneath dull, coarsely, closely, umbilicately punctured and rugose in front, less coarsely punctured behind as far as last abdominal segment which is still more finely punctured. Males much smaller than females with front femora dilated and anterior tibiae broadly and triangularly dentate within at middle and with a few short spines in front of dentation, the abdomen longitudinally impressed at middle, and last segment broadly and deeply impressed and rounded at apex; females with

all tibiae normal, the abdomen not impressed in front and last ventral segment impressed only near apex and with latter somewhat blunt. Males, length 6.5 mm., breadth 2.5 mm., females 8–10 mm. length by an average of 3 mm. wide.

The specimen so well illustrated by Boheman was evidently a large-sized female. The species was also listed by Boheman as from Panama but according to Blair was probably so listed in error, the real locality being one of the Galapagos Islands. Blair listed nine specimens from Eden Island, a small island near Indefatigable, and one from Indefatigable. The California Academy has two specimens from Indefatigable Island, including one fully as large as that figured by Boheman, one collected on Abingdon Island, September 8–23, 1906, and a large series, eighty specimens of average size, from various places in Albemarle Island: Villamil, Iguana Cove and Bank's Bay and a series of nine much smaller specimens, 5 mm. in length, from Albemarle Island, collected in March and April, 1906. With these smaller specimens I have associated one from Hood Island, collected September 24–30, 1905, not appreciably distinguishable. All of the above were collected by F. X. Williams except the largest female from Indefatigable which was collected May 4, 1932, by M. Willows, Jr., of the Templeton Crocker Expedition.

This sooty black species is a very distinct one and apparently only approached by two species, possibly offshoots isolated each on one of the smaller islands, *P. duncani* on Duncan Island and *P. opacus* on Jervis Island.

### ***Pedonoeces opacus* Van Dyke, new species**

Similar in general appearance to the above but both sexes are of about the same size as the males of *P. lugubris*, the differentiating features being that the punctuation of the head in *P. opacus* is coarse and much denser; that of the pronotum very much coarser, approximate, and somewhat aciculate; the hind margin of prothorax less deeply emarginate near angles thus reducing the prominence of the middle lobe and the extent to which the angles themselves project backwards; the carinae of the elytra less sharply carinate and more evidently and irregularly crenulate at apices, and the general surface duller and in general less evidently alutaceous. In the males, the front femora are dilated and angularly arcuate along the outer margin as in *P. lugubris* but in the front tibiae are normal; there is also often a tuft of pile on the posterior face of the middle femora near the base which seems to be absent in the other. Male, length 6 mm., breadth 2.5 mm., female, length 6.5 mm., breadth 3 mm.

*Holotype* male, allotype female and two paratypes, male and female, all collected on **Jarvis Island**, December 18-20, 1905.

The coarser sculpturing of head and pronotum, less sinuation of hind margins of prothorax, less sharply defined elytral carinae, and generally duller appearance should place this species apart from *P. lugubris*.

#### KEY TO SPECIES OF GENUS PEDONOCES G. R. WATERHOUSE

1. Elytral intervals flat or feebly elevated at most, striae fine and shallow; sparsely pilose; rather small and with rudimentary wings . . . . . 2
- Elytral intervals well elevated, convex or carinate, striae deeply impressed or sulcate . . . . . 4
2. Pronotal punctures very fine and well separated, elytral striae quite distinct and rather coarsely, closely punctured; general surface alutaceous and finely, sparsely pubescent . . . . . *P. pubescens* G. R. Waterhouse
- Pronotal punctures rather coarse, deep and close, elytral striae finely impressed and rather finely punctured; general surface more uniformly pubescent . . . . . 3
3. Strial punctures variable but those of intervals almost as evident as those of striae . . . . . *P. wenmani*, new species
- Strial punctures distinct and close, those of intervals very fine, elytra more or less shining . . . . . *P. culpepperi*, new species
4. Elytral intervals merely convex, not sharply carinate . . . . . 5
- Elytral intervals evidently carinate . . . . . 10
5. The intervals but moderately elevated and convex, striae and strial punctures fine, general surface more or less pilose under magn . . . . . 6
- The intervals well elevated but convex or blunt at apices, striae broad and deep, punctures coarse . . . . . 8
6. Prothorax two-ninths broader than long, sides somewhat arcuate, strial punctures of elytra fine and interstrial punctures very fine but distinct, elytral apex normal . . . . . *R. blairi*, new species
- Elytral apex prolonged or caudate in female . . . . . 7
7. Prothorax one-third broader than long, pronotum densely punctured but with punctures not contiguous, the lateral margins very distinct, rather broad, strial punctures of elytra rather coarse Hood Island . . . . . *P. caudatus*, new species
- Prothorax two-fifths broader than long, pronotum densely punctured and punctures more or less contiguous, the lateral margins fine, strial punctures of elytra fine and shallowly impressed. Tower Island . . . . . *P. apicalis*, new species
8. Pronotum somewhat coarsely, closely punctured, strial punctures approxi-

- mate, intervals very finely punctured, surface minutely pubescent.....  
 .....*P. uniformis*, new species
- Pronotum very finely, not closely punctured, striae punctures coarse and well spaced, surface glabrous ..... 9
9. Prothorax one-third broader than long, punctures fine, surface dull and alutaceous, sides more or less straight and parallel behind; elytra with sides parallel in front, intervals rather unequally elevated and always well rounded at summits; male femora simple ..... *P. bauri* Linell
- Prothorax less than one-third broader than long, punctures fine but deep, surface shining, sides sinuate behind, elytra subspatulate, intervals equally elevated and subcarinate; male femora with patches of erect golden pile ..... *P. galapagoensis*, G. R. Waterhouse
10. Elytral sulci distinctly punctured ..... 11
- Elytral sulci without distinct punctures ..... 17
11. Somewhat flattened, narrow and elongate species, pronotum rather coarsely, very densely punctured ..... 12
- More or less elliptical and conspicuously convex species ..... 13
12. Shining, pronotal punctures dense and sharply impressed, elytral intervals unequally elevated ..... *P. spatulatus*, new species
- Subopaque, pronotal punctures close but variolate, elytral intervals equally elevated ..... *P. barringtoni*, new species
13. Pronotum alutaceous and rather finely not closely punctured; elytral intervals equally elevated in front ..... 14
- Pronotum coarsely sculptured, the punctures large and more or less anastomosing ..... 15
14. Strial punctures fine, sulci and intervals obtuse angulated ..... *P. batesoni* Blair
- Strial punctures coarse, sulci broad and deep with narrow intervals ..... *P. morio* (Boheman)
15. Elytral intervals equally and sharply elevated and carinate ..... *P. duncani*, new species
- Elytral intervals unequally elevated ..... 16
16. Pronotum somewhat strigose as result of longitudinal anastomosing of punctures, punctures of head discrete; abdominal punctures rather fine ..... *P. costatus* G. R. Waterhouse
- Pronotum and head very coarsely punctured, punctures somewhat confluent but pronotum strigose, abdominal punctures coarse and close ..... *P. williamsi*, new species
17. Sooty, black species, pronotum very finely and closely punctured, hind angles somewhat acute, elytral costae sharply and smoothly defined, abdomen shallowly punctured and rugose, females often quite large ..... *P. lugubris* (Boheman)
- Dull black, opaque, the pronotal punctures coarse, contiguous and longitudinally anastomosing so as to give a strigose appearance; abdomen somewhat discretely punctured ..... *P. opacus*, new species

**Phaleria manicata** Boheman

## Plate VI, figure 1

*Phaleria manicata* BOHEMAN, 1858, Fregatten Eugenies Resa, I, p. 92

*Phaleria manicata* Boheman, C. WATERHOUSE, 1877, Proc. Zoo. Soc., V, p. 82.

*Phaleria manicata* Boheman, LINELL, 1898, Proc. U. S. Nat. Mus., XXI, p. 266.

*Phaleria manicata* Boheman, MITCHILLER, 1925, Zoologica, V, no. 20, p. 237.

Robust, ovate, somewhat convex, testaceous with variable black markings, upper surface smooth and alutaceous, and lateral margins of prothorax and elytra densely fimbriated with long yellowish pile. Head very finely, sparsely punctured and transversely impressed in front of eyes. Prothorax over one-third broader than long, apex broadly emarginate, base somewhat sinuate with feeble median lobe, sides almost straight and parallel or feebly sinuate at basal half and moderately arcuate and narrowed forwards, the disc finely and sparsely punctured and with a short longitudinal impression in front of scutellum and small fovea between impression and lateral angles. Elytra one-fifth longer than wide and three times as long and one-fourth broader at middle than prothorax, sides feebly arcuate from base to posterior third and then gradually rounded to apex, disc with striae well impressed, intervals convex and finely and sparsely punctured. Beneath unicolorous testaceous, smooth, finely alutaceous and very minutely and sparsely punctured. The feet robust as usual in genus, femora punctured and setaceous, tibia broadly dilated outwardly, the apex lobed on outer side, coarsely punctured, more or less setose and densely set with short stubby spines. Length 7 mm, breadth 4 mm.

This robust species is quite variable in color and color pattern, ranging from almost entirely testaceous above to almost entirely black, the lateral margins alone being testaceous. The usual color pattern is for the pronotum to be margined with black at apex and have a broad band at base; the elytra to have a broad transverse band near base, which is continued backwards two intervals wide, along the suture to near the middle where it becomes greatly expanded, often covering most of the disc, then narrowed to a sutural vitta as it approaches the apex.

Boheman's specimens are cited as coming from the Galapagos Islands without indicating any particular island. The California Academy of Sciences has a series of twenty-six more or less maculate specimens from Banks Bay, Albemarle Island, collected April 10-17, 1906, by F. X. Williams. This series I consider to be typical. Besides these, we have mounted a series of sixty-seven specimens of a praec-



tically immaculate phase from a series of several hundred specimens from Hood Island, collected during January and February, 1906, by F. X. Williams and a set of twelve smaller specimens with a small fuscous blotch at the middle of the elytra, four from Barrington Island, October 19-24, 1905, one from Charles Island, October 3, 1905, and six from Albemarle Island, March, 1906. These I consider but color phases of *P. manicata*. The genus is a wide spread one with representatives along the seacoasts of the continents of both the Old and New World.

### **Gnathocerus cornutus (Fabricius)**

*Trogosita cornuta* FABRICIUS, 1798, Supplem. Entomologica Syst., Hafnia, p. 51.

*Gnathocerus cornuta* (Fabricius), THUNBERG, 1814, Beshr. p. t. nya ins sl. Gnathocerus etc., Vetensk. Acad. Handl. p. 47.

*Gnathocerus cornutus* (Fabricius), LINELL, 1898, Proc. U. S. Nat. Mus., XXI, p. 266.

*Gnathocerus cornutus* (Fabricius), MITCHLER, 1925, Zoologica, V, no. 20, p. 237.

This cosmopolitan grain beetle which has an extensive bibliography of which I have given only the essential items, was first collected in the Galapagos Islands on Albemarle Island by Dr. B. Baur and recorded by Linell. Two specimens were also taken on Albemarle Island by F. X. Williams, in March 1906, three on James Island, January 5, 1906, and seven at Villamil, S. Albemarle, August 20, 1906. At the last location there is a permanent settlement so it is not surprising to find this cosmopolitan grain beetle there.

### **Alphitobius laevigatus (Fabricius)**

*Carabus laevigatus* FABRICIUS, 1781, Species Insect., I, p. 304

*Helops piceus* OLIVIER, 1792, Encycl. Method. Insect., VII, p. 50.

*Alphitobius picipes* STEPHENS, 1832, Ill. Brit. Mandib., V, p. 11.

This beetle, now widely distributed throughout the world by commerce, common in the Hawaiian Islands, was collected on Charles Island, May 23, 1906, by F. X. Williams. Eleven specimens were taken.

### **Rhacius costipennis Blair**

Plate VI, figure 3

*Rhacius costipennis* BLAIR, 1933, Ann. Mag. Nat. Hist., ser. 10, XI, p. 480.

This species has been but recently described and will not be considered further here.

The California Academy of Sciences possesses one specimen collected on Indefatigable Island, May 5, 1932, by M. Willows, Jr., of the Templeton Crocker 1932 Expedition. This specimen was carefully compared with the type by Dr. Blair and labeled as the same. The undersurface is bright rufous, contrasting strongly with the upper surface. There are but three described species in the genus

### Genus *Prateus* Le Conte

*Prateus* LeCONTE, 1862, Class. Col. N. Amer. (Smith Contr.), p. 238; 1866, New Spec. N. Amer. Col. (Smith. Contr.), p. 131.

*Lorelus* SHARP, 1876, Entom. Mo. Mag., 13, pp. 76-77.

The type of *Proteus* is *P. fuscus* Le Conte, from the middle and southern states of the United States; the type of *Lorelus* Sharp is *L. priscus* Sharp from New Zealand. According to Champion in notes in the British Museum of Natural History Collection, they are congeneric. Besides *P. fuscus* Le Conte, originally described from Texas, the genus contains numerous species described under *Lorelus* from Central and South America, New Zealand, and there are in the British Museum of Natural History collection, many undescribed species from southern Asia, Africa, and elsewhere. The general facies of these small members of the Tenebrionidae is that of the larger Cryptophagidae.

### *Prateus dentatus* Van Dyke, new species

Small, moderately elongate, more or less flattened, rufopiceous above, humeri lighter, the legs and underside rufocastaneous. Head rather coarsely and closely punctured, punctures almost contiguous in front, finely alutaceous, with feeble transverse impression in front of eyes; antennae almost reaching hind angles of prothorax, gradually and feebly clavate, third segment fully twice as long as second, fourth but little longer than broad, the fifth to tenth gradually more transverse and broader; eyes moderately convex, coarsely faceted, transverse, widest above and truncate posteriorly. Prothorax about a fourth wider than long, apex broadly emarginate and about one-fifth wider than base, base broadly lobed, the hind angles right and prominent; sides margined, feebly divergent from base almost to middle, thence arcuate and gradually rounded to apex and provided with four well marked denticles, two just behind middle, one-half way from middle to apex and the fourth between this and apex; the disc feebly convex, coarsely and closely punctured and with slight antescutellar impression and finely alutaceous. Scutellum moderate in size, transverse and feebly punctured. Elytra about twice as long

as broad and three times as long as prothorax, humeri rounded but almost rectangular, the sides gradually yet very feebly divergent from base to posterior third and thence evenly rounded to acute apices, the lateral margin well defined; disc somewhat flattened, coarsely and closely punctured, very sparsely and finely pilose, the individual fulvous hairs arising from the punctures, the humeral umbones prominent and without evidence of striae. Beneath coarsely and closely punctured in front and subopaque, more finely and distinctly punctured behind and shining, and with very sparse and minute fulvous pubescence. Length 4 mm., breadth 1.5 mm.

*Holotype*, a unique collected on **Indefatigable Island**, July 20-24, 1906, by F. X. Williams.

This small yet interesting species upon comparison with the extensive series in the British Museum of Natural History Collection was found to differ from all by having the sides of the prothorax more broadly rounded, the margins dentate, and the third segment of the antennae about twice as long as the second.

#### Family **ANOBIIDAE**

The California Academy of Sciences Expedition secured but two species of this family. The St. George Expedition of 1891, collected four species, two at light and the others from the herbage and rotting wood. These were described by Dr. Blair.

#### **Trichodesma denticollis** Blair

*Trichodesma denticollis* BLAIR 1928, Ann. Mag. Nat. Hist., ser. 10, vol. i, p. 675.

This species is not represented in the collection of the California Academy of Sciences.

#### **Thaptor galapagoensis** Blair

*Thaptor galapagoensis* BLAIR, 1928, Ann. Mag. Nat. Hist., ser. 10, vol. i, p. 676.

The California Academy of Sciences possesses one specimen collected at Academy Bay, Indefatigable Island, in January, between 18-22, 1906, by F. X. Williams.

#### **Eupactus georgicus** Blair

*Eupactus georgicus* BLAIR, 1928, Ann. Mag. Nat. Hist., ser. 10, vol. i, p. 676.

The California Academy has one specimen from Indefatigable Island, collected in November 17-19, 1905, by F. X. Williams that is possibly this species.

**Eupactus alutaceus** Blair

*Eupactus alutaceus* BLAIR, 1928, Ann. Mag. Nat. Hist., ser. 10, vol. i, p. 677.

This species is not represented in the collection of the California Academy of Sciences.

Family **BOSTRICHIDAE****Tetrapriocera longicornis** (Olivier)

*Apate longicornis* OLIVIER, 1795, Ent IV, nr. 77, p. 15, t. 3, f. 18

*Tetrapriocera schwarzi* HORN, 1878, Proc. Am. Phil. Soc., XVII, p. 545, f.

*Tetrapriocera longicornis* Olivier, LINELL, 1898, Proc. U. S. Nat. Mus., XXI, no. 1143, p. 256.

*Tetrapriocera longicornis* Olivier, MUTCHER, 1925, Zoologica, V, no. 20, p. 237.

Linell makes the following remarks concerning this species: "One example taken on Indefatigable Island by the Albatross Expedition in 1888. The species is distributed from southern Florida and West Indies to Central and South America." Mutchler in 1925 refers to this note but adds no new information. In the California Academy of Sciences Collection, is one specimen collected on Duncan Island, on December 1, 1906, by F. X. Williams. This specimen, I checked with a specimen of *Tetrapriocera tridens* Lesne (not Fabricius), a synonym of *I. longicornis* (Olivier), and found it to agree perfectly. It is also in agreement with three specimens labeled "*longicornis*" which we have from Florida.

**Micrapate scabratus** (Erichson)

*Rhizophorthera scabrata* ERICHSON, 1847, Wieg. Arch. f. Naturg., XIII, 1, p. 87.

*Bostrychulus scabratus* (Erichson), LESNE, 1898, Ann. Soc. Ent. Fr., LXVII, pp. 596, 612, 1-221.

*Micrapate scabrata* (Erichson), LESNE, 1938, Junk and Schenkling Coleopt. Cat., pars. 161, p. 46.

A single specimen from Chatham Island, collected May 23-29, 1906, by F. X. Williams, was compared in the British Museum of Natural History, with a specimen determined by Lesne as *Micrapate scabratus* (Erichson) and found to agree perfectly. This is a widespread species, being listed from Peru, Bolivia, and Chile.

**Amphicerus cornutus galapaganus** Lesne

*Amphicerus cornutus galapaganus* LESNE, 1910, Bull. Mus. Paris, pp. 184-186.

*Apate species* G. R. WATERHOUSE, 1845, Ann. Nat. Hist., XVI, p. 36.

*Amphicerus punctipennis* LeConte, LINELL, 1898, Proc. U. S. Nat. Mus., XXI, no. 1143, p. 256.

*Amphicerus cornutus galapaganum* Lesne, MUTCHLER, 1925, Zoologica, V, no. 20, p. 237.

This insect was first cited by G. R. Waterhouse in 1845, from Darwin species. Later these same specimens were studied by Lesne and pronounced a subspecies. The species "*cornutus*" is widely distributed throughout North and South America. The weak subspecies is supposedly confined to the Galapagos Islands.

In the material collected in the Islands during 1905-1906 by the California Academy Expedition, there is a series of seventy specimens, collected on the following islands: Hood, February, 1906; Abingdon, September, 1906; Wenman, September 24, 1906; Duncan, December, 1905; Albemarle, April 30, 1906; and Indefatigable, January 11-22, 1906. The specimens from Hood and Indefatigable are the largest. The series is quite uniform as to sculpturing and general appearance.

When compared with typical specimens *Amphicerus cornutus* (Pallas) of which we have one hundred and twenty-eight from various places in southern California, Arizona, Texas, Utah, Florida, Lower California, western Mexico, and Hawaii, members of the subspecies appear to be smoother, more shining, with the granulations over the basal portion of the pronotum less pronounced and the elytral sculpturing less rugose and the punctuation less coarse and better spaced.

### Family **SCARABAEIDAE**

This important family is but poorly represented in the Galapagos Archipelago, probably because of the general aridity of much of the region.

#### **Copris lugubris** Boheman

*Copris lugubris* BOHEMAN, 1858, Fregatten Eugenies Resa, I, p. 42

*Copris lugubris* Boheman, C. WATERHOUSE, 1877, Proc. Zoo. Soc. Lond., V, p. 82.

*Copris lugubris* Boheman, LINELL, 1898, Proc. U. S. Nat. Mus., XXI, no. 1143, p. 258.

*Copris lugubris* Boheman, MUTCHLER, 1925, Zoologica, V, no. 20, p. 237.

This species has not been collected subsequent to the voyage of the *Eugenie* in 1858. It may possibly never have been taken on the Galapagos Islands, for many of the species cited by Boheman were no doubt given erroneous localities through the carelessness of the collectors as has been frequently pointed out.

**Ataenius arrowi** Hinton

*Ataenius arrowi* HINTON, 1936, Ann. Mag. Nat. Hist., ser. 10, 17, pp. 414-416, f. 1-4.

*Ataenius cribrithorax* BLAIR, 1933, Ann. Mag. Nat. Hist., ser. 10, XI, p. 476.

The California Academy of Sciences has eleven specimens of this species: two from Tagus Cove, Albemarle Island, March 22, 1905, F. X. Williams, collector; two from Indefatigable Island, May 5, 1932, M. Willows, Jr., of the Templeton Crocker Expedition, collector; seven from Abingdon Island, September 18-23, 1906. This species is very close to *A. cribrithorax*. One of my Albemarle specimens has evident though reduced rugae at the sides of the head in front.

**Ataenius scutellaris** Harold

This beetle which is found in Mexico and the West Indies and extends well into South America, is characterized in the main by having the head coarsely punctured towards the base and gradually more finely so forwards and with the punctures fading out medially towards the front; with the pronotum convex and rather coarsely and densely punctured towards the sides and more finely towards the center; the scutellum sulcate and with a median longitudinal carina; and the elytra quite convex, with the humeral angles rectangular and toothed, the striae deeply impressed or sulcate, and somewhat obscurely punctured and the intervals greatly elevated, with an irregular row of punctures on either side and the median portion more or less carinated especially towards the sides.

The California Academy of Sciences has a series of fifty-two specimens, fifteen collected on Charles Island, April 30, 1906, twenty-four from Abingdon Island, September 8-23, 1906, one from Albemarle Island, April 24-27, 1906, and twelve from Chatham Island, January 1906, all by F. X. Williams.

**Trox suberosus** Fabricius

*Trox suberosus* FABRICIUS, 1775, Systema Entom., p. 31

*Trox suberosus* Fabricius, MUTEHLER, 1925, Zoologica, V. no. 20, pp. 229, 238

This rather large and common species of eastern North America which has been recorded from Central and South America as well as the West Indies and the Cape Verde Islands, was first reported from the Galapagos Islands by Mutehler, his single specimen having been taken on Tower Island, April 28, 1923, by the Harrison Williams Galapagos Expedition of the New York Zoological Society. The California

Academy of Sciences has twenty-one specimens: seven collected on James Island in December, 1905; one from Albemarle Island, in April 1906; three from Charles Island in April, 1906; two from Chatham Island, February, 1906; one from Hood Island, April 22, 1932, by M. Willows, Jr., of the Templeton Crocker Expedition of 1932; one from Abingdon Island, September 18-23, 1906; and five from Villamil, S. Albemarle Island, March 4-14, 1906, as well as two from Cowley Mountain, Albemarle, August 9-13, 1905, the majority collected by F. X. Williams. This species has well developed wings, hence the wide distribution in the Islands could be accounted for.

***Trox seymourensis* Mutchler**

Plate VI, figure 8

*Trox seymourensis* MUTCHLER, 1925, Zoologica, V, no. 20, pp. 229-230, 238.

In the California Academy of Sciences collection there are fifty-six specimens, most of which were collected at Villamil, S. Albemarle, August 20, 1906, by F. X. Williams, but there is one simply labeled "Albemarle Island, April 1906," another "Cowley Mt., Albemarle Island, July, 1906," and a well-worn elytron from Abingdon Island, picked up September 18-23, 1906. This species has well developed wings. The abundance of specimens from Villamil can be accounted for by the fact that there was a settlement there and some slaughtering carried on. Our Cowley Mountain specimen was carefully compared with Mutchler's type, both by Mr. Mutchler and myself, and found to be typical.

***Trox galapagoensis* Van Dyke, new species**

Plate VI, figure 7

Oblong, black, more or less covered with an earthen-colored indument. Head feebly convex, prolonged in front to an obtuse angle, slightly depressed at apex, sides also strongly angulate, the margins fimbriated and surface irregularly studded with short setae. Prothorax two-fifths broader than long, apex broadly lobed at middle and with the angles prominent and projecting well forward, the base broadly arcuate, sides lobed, feebly emarginate in front of right-angled hind angles, suddenly constricted at base and margined with short setae; the disc longitudinally and shallowly sulcate at middle with an obtuse and sinuous ridge on either side, an elongate tubercle near hind angles, and a deep and oblique impression in front of this, the surface covered with a dense earthy colored indument through which project short and scattered setae. Scutellum one-third longer than broad and broadly

sulcate in front. Elytra about one-seventh broader than long, with sides broadly arcuate from base to apex and margined with short widely spaced setae; the disc evenly convex, with ten well elevated intervals, the odd the most prominent, and each surmounted with a series of small tubercles from the apex of which projects a short seta; the striae with a series of large, deeply impressed pit like punctures with small tubercle-like elevated anterior and posterior margins. The legs much as in *T. scymourensis* but the front tibia with lateral spines more equal in size and closer together. The true wings appear to be little more than one-half normal size therefore not functional.

Length 10 mm., breadth 6.5 mm.

*Holotype*, a unique, collected **Culpepper Island**, in September 1905, by F. X. Williams.

This species is of about the same size as *T. scymourensis* but differs by having a very different type of elytral sculpturing as indicated by the more regular elevation of the elytral intervals surmounted by small crater-like tubercles and the regular arrangement of the striae punctures, in *T. scymourensis*, striae and striae punctures appear to be absent.

### **Neoryctes Arrow**

*Neoryctes* ARROW, 1908, Trans. Ent. Soc. Lond., p. 342

*Parapseudoryctes* MUTCHLER, 1925, Zoologica, V, no. 20, pp. 237-238.

*Pseudoryctes* LINELL, 1898, Proc. U. S. Nat. Mus., XXI, no. 1143, p. 258.

*Oryctes* Illiger, G. R. WATERHOUSE, 1845, Ann. Nat. Hist., XVI, pp. 26-27.

The genus *Neoryctes* was proposed by Arrow to replace *Pseudoryctes* Linell, the name of which was found to be preoccupied. Mutchler, not seeing the citation, later on also proposed a new name, *Parapseudoryctes*. *Neoryctes* of course has priority. Linell, however, was the first to note that the species "*galapagoensis*" of G. R. Waterhouse was very different from those associated under the Old World genus *Oryctes*, the genus to which Waterhouse assigned it, so erected the genus *Pseudoryctes* to receive it.

### **Neoryctes galapagoensis (G. R. Waterhouse)**

Plate VI, figure 5

*Oryctes galapagoensis* G. R. WATERHOUSE, 1845, Ann. Nat. Hist., XVI, pp. 26-27.

*Oryctes galapagoensis* G. R. Waterhouse, C. WATERHOUSE, 1877, Proc. Zoo. Soc., V, p. 82.

*Oryctes galapagoensis* G. R. Waterhouse, HOWARD, 1889, Proc. U. S. Nat. Mus., XII, no. 771, p. 191.

*Pseudoryctes galapagoensis* (G. R. Waterhouse), LINELL, 1898, Proc. U. S. Nat. Mus., XXI, no. 1143, p. 250.



*Neoryctes galapagoensis* (G. R. Waterhouse) ARROW, 1908, Trans. Ent. Soc. Lond., p. 342.

*Parapseudoryctes galapagoensis* (G. R. Waterhouse), MUTCHELER, 1925, Zoologica, V, no. 20, pp. 237-238.

Mr. Waterhouse does not indicate from what island the species that he described came from. Linell states that the Albatross Expedition in 1888 collected one female on Chatham Island, the female that he undoubtedly used for drawing up his generic description, and that Dr. G. Baur obtained six males on the same island. No other specimens seem to have been collected between that date and 1938 when Mutchler separated out his species, *N. linelli*, from the known specimens. In 1905-1906, F. X. Williams collected fourteen specimens including both males and females, which run to *N. galapagoensis*, these came from the following localities: Chatham Island, July, 1906; Charles Island, March, 1906; and Cowley Mountain, Albemarle Island, July, 1906. These specimens range in size from 15 mm. to 17 mm. in length. The wings, though present, are much reduced in size and nonfunctional. Besides these are four large females, averaging 28 mm. from Chatham Island, July, 1906, that seem to fit Mutchler's species, *N. linelli*.

### **Neoryctes linelli** Mutchler

*Neoryctes linelli* MUTCHELER, 1938, Am. Mus. Novitates, no. 981, pp. 10-11, figs 10, 11 and 12.

The California Academy of Sciences has four specimens from Chatham Island, collected in July, 1906, by F. X. Williams.

### **Neoryctes** sp. ?

Two specimens of the same size and general appearance as *N. galapagoensis* were collected on Indefatigable Island, one on May 2, 1932 by M. Willows, Jr., of the Templeton Crocker Expedition, the other on March 1906, by F. X. Williams. These are much smoother, more shining, in general more finely punctured, with the prothorax wider, and with the sides more broadly rounded. These I have set aside for further study. They may be new or merely a variety of *N. galapagoensis*.

## **Family PASSALIDAE**

### **Passalus interruptus** Linnaeus

*Passalus interruptus* LINNAEUS, 1754, Mus. Adolph. Frieder; p. 82.

*Neleus tlascala* PERCHERON, 1835, Monogr. des Passales, etc., p. 35, t. 3, f. 5.

*Neleus tlascala* Percheron, LINELL, 1898, Proc. U. S. Nat. Mus., XXI, no. 1143, p. 257.

*Neleus tlascala* Percheron, MUTCHLER, 1925, Zoologica, V, no. 20, p. 238.

*Passalus interruptus* Linnaeus is a rather large species which ranges from Texas to Argentine. Under the name *Neleus tlascala* Percheron, a synonym of the above, Linell lists a specimen as having been taken by the Albatross Expedition in 1891, on Charles Island. No specimens have been taken since. Numerous specimens collected on Cocos Island, by F. X. Williams, are much smaller than *P. interruptus*, and have been proven to be *Popilius lenzi* Kuwert.

### Family CERAMBYCIDAE

This family, rich in South American species, has numerous representatives in the Galapagos Archipelago, some of which are also to be found on the South American mainland but most are restricted to the islands.

#### *Parandra galapagoensis* Van Dyke, new species

Male: rather large, elongate, subcylindrical, smooth and shining, dark rufous with legs and undersurface of afterbody a lighter color; the greater part of the head including most of the mandibles, eyes, and sides of head more or less black, the pronotum generally with an almost complete and fine marginal black line, likewise the apices of femora, tibiae, and tarsal segments black or at least dark in color.

Head transverse, front feebly convex, sparsely punctured, a well marked triangular impression at middle of front margin and the post-ocular region coarsely punctured and rugose; mandibles large, arcuate, as long as head, notched at apices, inner margin with a blunt tooth one-fourth distance back from apex and three or four smaller yet evident blunt teeth near middle, the entire surface also rather finely and sparsely punctured though more densely so towards apices; antennae almost reaching hind angles of prothorax, segments 4-6 triangular and as long as broad, 7-10 also triangular but longer than broad and eleventh fusiform and about three times as long as broad; eyes moderately prominent, evenly arcuate in front, suddenly constricted behind causing them to stand out prominently; submentum very coarsely punctured with punctures more or less anastomosing, the front margin smooth and flattened and anterior angles prominent and smooth except for a series of small punctures. Prothorax three-eighths wider than long at middle, narrower than head across eyes, apex broadly emargi-

nate, base feebly arcuate; sides, from obtusely rounded hind angles, divergent and oblique almost to middle, then straight and parallel to apex, the marginal bead broader posteriorly; disc flattened above and minutely, sparsely punctured. Scutellum cordiform and smooth except for a few small punctures. Elytra almost twice as long as broad, 15 mm. to 8 mm., three times as long as prothorax, the sides almost straight and parallel to posterior third thence arcuate and narrowed and suddenly rounded to apices; disc smooth and practically impunctate, the few very minute punctures only observed under considerable magnification. Beneath, the base of head and prothorax finely, sparsely punctured, the meso- and metasternum finely punctured and finely pilose and the abdomen rather coarsely, shallowly punctured and dull especially towards sides and apex. Wings large and fully developed. Length 28 mm., breadth 8 mm.

Female: Similar to male as far as color and general appearance go but with head smaller, frontal punctures finer and sparser, the post-ocular punctures also sparse and well separated; the mandibles short, two-thirds length of head, feebly arcuate. Emarginate at apex with pronounced tooth at inner part of notch, a vague tooth at middle of inner surface and two pronounced teeth, united at base near base of inner margin; the antennae somewhat shorter and with basal segments more transverse; and the submentum rather coarsely, sparsely punctured. Prothorax four-thirteenths broader than long, with sides rather evenly arcuate and feebly narrowed forwards. Length 23 mm., breadth 7 mm.

*Holotype* male, **James Island**, January 1906; allotype female, James Island, December, 1905; and several designated paratypes from a series of seventy-six specimens from James Island. There are also two rather small specimens from Indefatigable Island, January 11, 1906, and four somewhat larger females from San Tomas, Albemarle Island at 1200 feet altitude, collected September, 1906. Mr. F. X. Williams who collected all specimens tells me that he chopped all specimens out of rotten logs, on the mountain tops.

This species was compared with all Central and South American species in the British Museum of Natural History collection and not found to agree with any. It runs to *P. brachyderes* in Lameere's (1902) key, but differs from a cotype of the same in the British Museum in that the upper surface is very smooth, rather finely and sparsely punctate, and has long curved mandibles in the male in contrast to the almost straight mandibles in *P. brachyderes* which are without teeth along the inner border; by having large and confluent punctures behind the eyes in contrast to moderately coarse and well spaced ones;

by the antennae having the segments 4-6 as long as broad, 7-10 longer than broad and the eleventh at least three times as long as broad, the segments in brachyderes 4-8 being longer than as broad, 9-10 as long as broad, and the eleventh about twice as long as broad; the undersurface of the head coarsely and confluent punctured. In *P. galapagoensis* most of the undersurface posteriorly is quite smooth whereas it is well punctured anteriorly in the other. All the Lameere specimens of *P. brachyderes* come from Mexico.

### **Stenodontes molarius** (Bates)

*Mallodon molarium* BATES, 1879, Biol. Centr. Amer., Col V, p. 9.

*Mallodon molarium* Bates, HOWARD, 1889, Proc. U. S. Nat. Mus., XII, no. 771, p. 191.

*Mallodon molarium* Bates, LINELL, 1898, Proc. U. S. Nat. Mus., XII, no. 1143, p. 259.

*Stenodontes molarius* (Bates), MUTCHLER, 1925, Zoologica, V, no. 20, p. 238.

As mentioned by Linell: "The Albatross expedition in 1888 collected on Charles, Chatham, and Auxiean islands seventeen examples of this large Prionid, which is distributed from Lower California through Mexico and Central America to Panama. The species is amply winged."

The California Academy of Sciences has a series of twenty-four specimens from the Galapagos Islands, including six females, and from the following localities: Chatham Island, four, January, 1906, three, July 1906, Indefatigable Island, eight on January 2, 1906, and three in July, 1906; and Villamil, south Albemarle Island, six on March 22, 1906; all collected by F. X. Williams. The Villamil specimens are all considerably smaller than those from the other islands which are large, apparently of normal size. The Academy's specimens, especially the large males, are characterized by having the mandibles curved, the inner face concave and the front of the head very coarsely, rugosely, and approximately punctured. Mexican specimens, with which they have been compared, generally have the mandibles straighter and the punctuation of the head less rugose and less approximate. The island specimens thus appear to be a variety or weak subspecies.

A second species described by Mutchler, appears to me to be somewhat pathological, especially as regards the mandibles which are so rotated as to have the inner face turned upwards. It also comes from Indefatigable Island from whence Mutchler received fourteen specimens and the California Academy eleven specimens of *S. molarius*.

**Stenodontus (Mallodon) galapagoensis** Mutchler

*Stenodontus (Mallodon) galapagoensis* MUTCHLER, 1925, Zoologica, V, no. 20, pp. 11-12, plate, fig. 6.

The California Academy of Sciences does not possess specimens of this species.

**Strongylaspis kraepelini** Lameere

Plate VII, figure 5

*Strongylaspis kraepelini* LAMEERE, 1903, Mem. Soc. Ent. Belg., XI, p. 28 (Revision Prionides); 1919, Gen. Insect. (Wytzman), fasc. 72, p. 25, pl. 2, f. 4.

Large, robust, subcylindrical, dark reddish brown. Head of moderate size, slightly more than one-half width of prothorax, coarsely punctate-rugose, punctures somewhat finer behind eyes, larger punctures finely setiferous, narrowly longitudinally sulcate at middle, the clypeus triangular and flattened and depressed in front and in common with base of mandibles clothed with rather long golden pile, genae prominent and dentate, extending somewhat forward; mandibles short but robust and with well marked tooth near apex; antennae reaching the middle of elytra or a little beyond, more robust in male, first segment robust. Clavate and with large punctures, generally well separated but often confluent; second segment small, as broad as long in female, slightly longer than broad in male, third segment equal to fourth plus one-half of the fifth in female, and in male equal to the fourth plus a third of fifth, the terminal segments distinctly striate; eyes large and coarsely granular. Prothorax less than twice as wide as long, apex broadly yet feebly lobed at middle, front angles prominent, base broadly arcuate, sides with prominent and acute spine near base, sometimes dentate, then feebly arcuate and convergent forward to front angles and with margins irregularly serrate; disc convex, in female with general surface moderately coarsely and closely punctured and asperate, a well marked median groove extending from base two-thirds forward, the front portion more flattened and smooth and the smooth area connected laterally with a raised arcuate callosity which broadens out apically in the form of tubercules some distance before the front angles, the male with the punctures much coarser and more irregular, the median groove hardly evident, but the median smooth area becoming an irregular transverse callosity, the median basal area also somewhat elevated and smooth and the anterior arcuate line sharply elevated. Scutellum transverse and acutely granulate. Elytra less than two and one-half times as long as broad, almost five times as

long as prothorax, the disc rugose and punctate, with two well defined carinae besides broader and obtuse lateral carinae, the basal area granular and the sutural apices feebly dentate, the males with sculpturing more pronounced than in females. Length 30 mm., breadth 11 mm.

Three female specimens of this fine prionid were collected on James Island, during December, 1905, by F. X. Williams. One of these was compared with specimens from the type material kindly sent to the British Museum for my use by Hans Gebien of the Hamburg Museum. I also have a male from the type locality, Ecuador. According to Lameere, this species belongs in the true subgenus *Strongylaspis*, with the third antennal segment longer than the fourth and one-half of the fifth segment combined, the antennae not attaining the posterior third of the elytra in the female nor the extremity in the male. He considers it as an admirable transitional form between *Chiasmotus linnaei* Guérin-Ménéville and *Strongylaspis* of Central America. The Galapagos Island record for this species is its first record outside of the type locality record from Guayaquil, Ecuador.

### ***Achryson galapagoensis* Linell**

Plate VII, figure 6

*Achryson galapagoensis* LINEELL, 1898, Proc. U. S. Nat. Mus., XXI, no. 1143, p. 259.

*Achryson galapagoensis* Linell, MITCHLER, 1925, Zoologica, V, no. 20, p. 238

The California Academy of Sciences collection contains eighteen specimens, ten collected on Chatham Island, February 23, 1905, two on same island in July, 1906, and three collected on South Seymour Island, July, 1906, by F. X. Williams, and a small male collected on Charles Island, May 15, 1932, by M. Willows, Jr., of the Templeton Crocker Expedition of 1932. The series shows considerable variation in size and in the size and arrangement of markings, the Charles Island specimen not only being quite small but with the dark markings more evident than usual.

This species which is quite distinct from the well known and widely distributed *Achryson surinamum* (Linnaeus), found throughout eastern North America as well as much of South America, has hitherto been considered to be restricted to the Galapagos Islands. This is, however, not the case for I found in the British Museum of Natural History collection, fourteen specimens from the following localities: two from Eton, Peru; five from Chile; one from Quito, Ecuador; one from Colombia; and five without locality labels; all of the above could not be separated from the Galapagos Islands specimens. A Peruvian

specimen was absolutely identical with the specimen that I took abroad for purposes of comparison. This South American lot bore the manuscript name of *A. lineolatum* Chevrolat. It thus appears that this species is widely distributed throughout western South America as well as found in the Galapagos Islands.

### ***Eburia lanigera* Linell**

*Eburia lanigera* LINELL, 1898, Proc. U. S. Nat. Mus., XXI, no. 1143, p. 259.

*Eburia lanigera* Linell, MUTCHLER, 1925, Zoologica, V, no. 20, p. 238.

*Eburia lanigera* Linell, BLAIR, 1933, Ann. Mag. Nat. Hist., ser. 10, XI, pp. 480-481.

The St. George Expedition of 1924 obtained two specimens of this species, one from James Island and one from Eden Island. Dr. Blair after reporting these, comments as follows:

“This appears to me to be only a variety of the Central-American and West-Indian *E. stigma* Oliv. Linell made no comparison with this species nor gave any indication of its position in the genus. Both Mr. Bateson's specimens have much shorter spines on both femora and elytra than normal *E. stigma*.”

The California Academy of Sciences possesses nineteen specimens of this species, collected by F. X. Williams from the following localities: three from Gardner Island near Hood, January, 1906; five from Chatham Island, February, 1906; two from Albemarle Island, one collected in December, 1905, the other April, 1906, one from Hood Island, November, 1905; four from Jervis Island, December, 1905; and four from Duncan Island, December, 1905. The entire lot are fairly uniform as to character. It is thus apparent that this beetle is the most common and widely distributed species of *Eburia* on the Islands.

### ***Eburia proletaria* Erichson**

*Eburia proletaria* ERICHSON, 1847, Arch. fur Naturgesch., XIII, i, p. 140.

*Eburia proletaria* Erichson, BLAIR, 1933, Ann. Mag. Nat. Hist., ser. 10, XI, p. 481.

*Eburia bauri* LINELL, 1898, Proc. U. S. Nat. Mus., XXI, no. 1143, p. 260.

*Eburia bauri* Linell, MUTCHLER, 1925, Zoologica, V, no. 20, p. 238.

Elongate, subcylindrical, reddish brown, rather densely clothed with appressed grayish yellow pile and scattered hairs, especially evident on antennae, legs and upper surface. Head somewhat flattened between eyes; antennae long, in the male reaching four segments beyond apex of elytra, scape robust, subearinate, two-thirds length of third, smooth and darker at apex, the third to eleventh filiform. Pro-

thorax slightly broader than long, somewhat more narrowed in front than behind, sides arcuate with prominent acute tooth at middle and blunt tubercle nearer apex than median tooth; disc convex, with sparse granules, a faint median carina behind middle and a prominent, somewhat acute tubercle on either side of middle slightly in front of the center; the discal tubercles, the lateral teeth and tubercles and front margin black. Scutellum transverse and more densely pilose than elytra. Elytra less than three times as long as broad and less than three times as long as prothorax, convex, emarginate and bispinose at apex, the sutural spines the shorter; disc with granules rather numerous towards base, very sparse and irregular apically, a pair of light yellow elongate and elevated ivory spots at base of each elytron, each pair midway between humerus and scutellum and the inner spots about twice length of outer, and another pair of similar spots at about the middle and midway between suture and sides of each elytron, with the outer spots about three times length of inner, and in addition a black area posterior to anterior spots and more or less surrounding the posterior spots. Legs slender, middle and posterior femora bispinose at apices with inner spines about three times as long as short outer ones, the posterior femora extending slightly beyond apex of elytra. Length 23 mm., breadth 6 mm.

The California Academy of Sciences has four specimens collected by F. X. Williams, including a typical male from Chatham Island, collected in February, 1906, which was carefully compared with specimens in the British Museum of Natural History. This served for the basis of the description given above. A second specimen, a large male, 28 mm. in length, was likewise collected on Chatham Island, February 25, 1906. This specimen was also lighter in color, more ochraceous, and without black markings of any sort. In general appearance, it agreed with many of the lighter specimens in the British Museum. A third specimen was from James Island, in December, 1905, this agrees perfectly with the first-mentioned specimen. The fourth specimen was reared from wood collected in the Islands by F. X. Williams. It emerged in the rooms of the Department of Entomology, July 21, 1914. Later on it was sent to Washington and compared with the type of *Eburia bauri* Linell by W. S. Fisher and pronounced to be the same species. On the strength of this I have suppressed *Eburia bauri* Linell as a species.

Dr. Blair mentions one specimen of *E. prolectaria* as having been taken by C. L. Collenette of the St. George Expedition at Tagus Cove, Albemarle Island, which agrees in all essentials with examples from Peru. I examined this specimen and also noted that in the British



Museum there is a large series of *E. proletaria* from many parts of western South America such as Guyaquil in Ecuador, Colombia, Peru, Bolivia, and Chile. When compared with *E. lanigera*, *E. proletaria* stands out as larger and of a more rufous color, the other being dominantly piceous with gray pile, with the discal and anterior lateral tubercles of the prothorax more prominent and the apical spines of the elytra and the femoral spines more unequal.

### ***Eburia amabilis* Boheman**

*Eburia amabilis* BOHEMAN, 1858, Fregatten Eugenie Resa, I, p. 150.

*Eburia amabilis* Boheman, C. WATERHOUSE, 1877, Proc. Zoo. Soc., VI, p. 82.

*Eburia amabilis* Boheman, HOWARD, Proc. U. S. Nat. Mus., XII, p. 192.

This species has apparently never been taken since the voyage of the *Eugenie* or at least recognized since then.

The California Academy of Sciences has no specimen of this species.

### ***Compsa apicalis* Blair**

*Compsa apicalis* BLAIR, 1933, Anns. Mag. Nat. Hist., ser. 10, XI, p. 481

No specimens of this species are in the California Academy of Sciences collection.

### ***Desmiphora hirticollis* Olivier**

*Desmiphora hirticollis* OLIVIER, 1795, Ent. IV, 68, p. 11, t. 4, f. 37.

*Desmiphora mexicana* THOMSON, 1860, Class. Ceramb., p. 75.

*Desmiphora mexicana* Thomson, BATES, 1886, Biol. Centr.-Amer., V, p. 116

*Desmiphora hirticollis* Olivier, BLAIR, 1933, Ann. Mag. Nat. Hist., ser. 10, vol. XI, p. 482.

This species, one specimen of which was taken by the St. George Expedition of 1924, on James Island at light (C. L. Collett), and reported by Blair, is a common and widely distributed tropical-American species occurring from Mexico and the West Indies to the Argentine.

The California Academy of Sciences has no specimens from the Galapagos Islands.

### ***Estola galapagoensis* Blair**

Plate VII, figure 4

*Estola galapagoensis* BLAIR, 1933, Ann. Mag. Nat. Hist., ser. 10, XI, p. 482

The three specimens in the California Academy of Sciences collection were collected on Albemarle Island, one on December, 1905, the

others at San Tomas, altitude 1200 feet, Albemarle Island September, 1906, both by F. X. Williams. The December specimen was checked with the type and labeled as a paratype by Dr. Blair.

### ***Estola cribrata* Blair**

*Estola cribrata* BLAIR, 1933, Ann. Mag. Nat. Hist., ser. 10, XI, p. 483.

This species is lacking in the collection of the California Academy of Sciences.

### ***Estola insularis* Blair**

*Estola insularis* BLAIR, 1933, Ann. Mag. Nat. Hist., ser. 10, XI, p. 483.

The California Academy of Sciences possesses two specimens of this species, agreeing perfectly with the description and collected on Indefatigable Island, January 11, 1906, and James Island, January 5, 1906, both by F. X. Williams.

### ***Estola duncani* Van Dyke, new species**

Rather small, elongate, yet closely knit, reddish brown, sparsely clothed with closely appressed rufous pubescence with here and there a few tufts of lighter color to give it a slightly maculated appearance, and with short, much inclined black setae somewhat uniformly though sparsely dispersed over the surface of the elytra. Head rather wide, somewhat flattened, coarsely but not closely punctured, with a narrow, median impunctate longitudinal line between the eyes; pubescence short and depressed and with a few short setae about the eyes and on the occiput; antennae robust, annulated, the base of each segment pale, reaching to posterior third of elytra, third segment slightly shorter than fourth, the following gradually shorter, with a few hairs fringing the under surface. Prothorax transverse, convex above, with short lateral tubercles situated just behind the middle, disc with coarse and rather closely placed punctures from each of which arises an inclined seta, the intervening areas clothed with the maculated rufous and gray pile. Elytra three-sevenths longer than wide and three and a half times as long as prothorax, gradually narrowed from shoulders, with punctures coarser and less closely placed than on pronotum yet numerous and with the setae arising from them somewhat larger than on pronotum and black. Beneath with vestiture much as on upper surface but the punctures more widely spaced and giving the surface a spotted appearance. Length 10 mm., breadth 4 mm.

*Holotype*, a unique, collected on **Duncan Island**, during December, 1905, by F. X. Williams.

This species is apparently somewhat similar to a number of unnamed South American species, specimens of which I examined in the British Museum of Natural History Collection, yet different from any.

***Acanthoderes galapagoensis* Linell**

Plate VII, figure 2

*Acanthoderes galapagoensis* LINELL, 1898, Proc. U. S. Nat. Mus., XXI, no. 1143, p. 261.

*Acanthoderes galapagoensis* Linell, MUTHLER, 1925, Zoologica, V, no. 20, p. 238.

This conspicuous cerambycid is apparently widely distributed throughout the Archipelago. Mr. F. X. Williams collected one specimen on March 2, 1906, on Albemarle Island, a second at Villamil, Albemarle Island, August 20, 1906, and seven specimens in January, 1906, on James Island. Both sexes are represented.

***Leptostylus galapagoensis* Van Dyke, new species**

Plate VII, figure 1

Rather small, robust, a reddish brown color which is mostly concealed above the short dense, closely appressed scalelike, chalky white pubescence, uniform except for a small brown patch of pubescence near suture and slightly in advance of apex and a smaller patch near elytral margins on a level with the hind femora, the punctuation of both pronotum and elytra conspicuous because of the punctures not being covered by the dense pubescence. Head with posterior margin and a sharply defined median longitudinal line extending from occiput to clypeus denuded of pile; eyes strongly reniform, well separated above and coarsely faceted; antennae long and delicate, extending four and a half segments beyond elytral apex in males, third segment shorter than fourth and slightly more robust, the following segments gradually shorter. Prothorax considerably more than a third broader than long with a short acute tubercle on lateral margin, slightly behind the middle, the sides feebly arcuate and convergent forwards from spine and straight and parallel to base behind spine; disc transversely impressed behind apex and in front of base, with two low tubercles, one on either side of middle, a short denuded median line between middle and base and rather densely and somewhat coarsely punctured, the punctures conspicuous because uncovered by pile. Scutellum unclothed medially. Elytra over two-sevenths longer than wide, broad

at base with prominent humeri, gradually narrower behind; disc with prominence at middle of each elytron near base and a feeble ridge extending from humeri obliquely inwards almost to apex, the rest of surface densely and finely pubescent except for the uncovered conspicuous punctures which are more or less regularly scattered over the surface, the punctures separated from each other by from two to several times their diameter. Beneath densely, uniformly clothed with fine white pile, the punctuation concealed. Legs stout. Length 10 mm., breadth 4.75 mm.

*Holotype* male and several designated paratypes from a series of eighteen specimens collected at **Villamil, South Albemarle Island**, March 14, 1906, by F. X. Williams. Mr. Williams also collected one specimen on James Island, March 2, 1906, and one specimen on Jervis Island, December 18, 1905.

This attractive chalky-colored species should be readily recognized. It is placed in *Leptostylus* for it agrees with the members of that genus in having the sides of the prothorax angulate behind the middle, the scape more or less cylindrical, antennae without cilia, broad mesosternum and rather short hind metatarsus but differs from typical species by the fact that the sides of the prothorax are acutely tuberculate, not bluntly tuberculate, and the mesosternum provided with two short posterior tubercles.

Females are needed to see whether they have a pronounced exposed ovipositor or not. Almost no South American species of the genus are known though the group is well represented in Mexico. This and the following species also show certain relationships with Bate's *Atrypanus* and associates like *Trypanidias*, more strictly southern genera, but lack the elongated lower lobe of the eyes of the former and the long ovipositor of the latter. In *Atrypanus* we have a genus which strongly suggests our species because of the presence of the posterior lateral tubercles on the mesosternum but the eyes are very different.

### ***Leptostylus williamsi* Van Dyke, new species**

Quite small, reddish brown, rather densely clothed with short and closely appressed scalelike pile which is in the main white; marked with a small transverse black marking at shoulders, a bare irregular and somewhat triangular patch at sides behind the middle, which reaches the outer margin but not quite to the suture, two small spots subapically, one along suture, the second near side margin, and a series of five or six black dots extending along the suture

behind the middle, the small pronotal punctures somewhat evident because unclothed but the elytral punctures less conspicuous as more or less concealed by the vestiture. Head with impressed median longitudinal line unclothed; eyes strongly reniform, narrowly separated above and coarsely faceted; antennae long and delicate, reaching about five segments beyond apex of elytra, scape somewhat sinuous and subcylindrical outwardly and feebly fuscous towards apex, the third segment shorter than the fourth, the following gradually shorter. Prothorax less than twice as wide as long, the lateral tubercles very acute, almost spiniform and placed as usual slightly back of middle, sides barely arcuate, almost straight and convergent forwards from the spines, straight and parallel behind; disc transversely impressed back of apex and in front of base, with a small tubercle on each side of middle and rather densely punctured; the punctuation evident because not covered by the pile. Scutellum bare at middle, tufted laterally. Elytra about twice as long as broad and almost five times as long as prothorax, widest at base, humeral angles prominent, gradually narrowed posteriorly, apices of elytra feebly and obliquely truncate; disc with elongate tubercle near middle of each elytron close to base and a feeble ridge reaching from humeri, obliquely inwards almost to apex, the surface densely pubescent but with scattered punctures more or less conspicuous. Beneath densely uniformly pilose, the pile finer and not scalelike, punctuation concealed; the two small tubercles at hind margin of mesosternum hardly visible. Legs stout, the clavate portion of hind femora and tibiae fuscous. Length 6 mm., breadth 2.25 mm.

*Holotype*, collected on **James Island**, March 2, 1906, by F. X. Williams; a paratype collected at Academy Bay, Indefatigable Island, March 24, 1925, by the Templeton Crocker Expedition; and a specimen since badly injured by *Anthrenus*, collected on Jervis Island, December 18, 1905, by F. X. Williams. The Indefatigable Island specimen is slightly smaller than the holotype and with the color pattern more definite. The Jervis Island specimen was larger than either of the others and with the markings rather inconspicuous.

This little species differs from the preceding by being in general considerably smaller and proportionally narrower, with a decided maculate color pattern and by having the dorsal punctuation of both prothorax and elytra finer and less evident. It is distinctly congeneric with the preceding, in fact very closely related, having the same acute lateral tubercles to prothorax, the small tubercles on hind margin of mesosternum somewhat conspicuous and the dorsal punctuation uncovered by the vestiture and therefore quite evident.

**Taeniotes hayi** (Mutchler)

*Monochammus hayi* MUTCHLER, 1938, Am. Mus. Novitates, no. 981, p. 13, pl. fig. 3.

*Monochammus cocoensis* MUTCHLER, 1938, Am. Mus. Novitates, no. 981, p. 13.

[Dr. Van Dyke retained this species in *Monochammus*. The present generic assignment and synonymy conforms to Dillon and Dillon (1941, p. 17).]—Ed.

\*  
Family **CHRYSOMELIDAE**

This family is very poorly represented on the Galapagos Islands. There are, however, several species that are definite representatives of its fauna while a number of others that have been attributed to it, chiefly well-known Central and South American species which have no doubt been collected by careless collectors and wrongly attributed to the Islands. This is no doubt the case with the following: *Doryphora gucrini* Stal, var., *Diabrotica ventricosa* Jacoby, and *Physonota alutacea* Boheman, species collected by members of the St. George Expedition of 1924, and listed by Blair as from the Islands.

I believe that the above were all collected on the mainland, later taken to the Islands and mixed with local material. Those definitely known to occur on the Islands are the following:

**Metachroma labrale** Blair

*Metachroma labrale* BLAIR, 1933, Ann. Mag. Nat. Hist., ser. 10, XI, p. 484.

The California Academy of Sciences has one specimen of this species, collected on Indefatigable Island, in October, 1905, which was compared with Blair's type, and sixteen specimens collected at Villamil, South Albemarle on March 4-14, 1906. Most of the specimens have a greenish gloss to the upper surface. The species is fully winged.

**Diabrotica limbata** C. Waterhouse

*Diabrotica limbata* C. WATERHOUSE, 1877, Proc. Zoo. Soc. Lond., pp. 81-82.

*Diabrotica limbata* C. Waterhouse, MUTCHLER, 1925, Zoologica, V, no. 20, p. 238.

This species has not been collected by any of those who have visited the Islands since Darwin's time.

**Docema** Charles Waterhouse

*Docema* C. WATERHOUSE, 1877, Proc. Zoo. Soc. Lond., p. 80.

***Docema galapagoensis* (G. R. Waterhouse)**

*Haltica galapagoensis* G. R. WATERHOUSE, 1845, Ann. Nat. Hist., XVI, pp. 39-40.

*Docema galapagoensis* (G. R. Waterhouse), C. WATERHOUSE, 1877, Proc. Zoo. Soc. Lond., p. 81.

*Haltica galapagoensis* G. R. Waterhouse, LINELL, 1898, Proc. U. S. Nat. Mus., XXI, p. 262.

*Docema galapagoensis* (G. R. Waterhouse), MITCHLER, 1925, Zoologica, V, no. 20, p. 238.

The California Academy of Sciences has a series of fifty-five specimens: one from Charles Island, May 17, 1932, the type locality; five specimens from Jervis Island, June 6, 1932; and three specimens from Tagus Cove, Albemarle Island, March 23, 1932; all collected by M. Willows, Jr., of the Templeton Crocker Expedition of 1932; and thirty-seven specimens from Albemarle Island, April 24-26, 1906, collected by F. X. Williams. They are all black above and agree in every way with the description except that there is a variation in the color of the legs.

***Docema darwini* Mutchler**

*Docema darwini* MITCHLER, 1925, Zoologica, V, no. 20, pp. 230, 238.

A specimen collected by F. X. Williams for the California Academy of Sciences was collected on Chatham Island, in February, 1906. It has been carefully compared with one of Mutchler's paratypes. According to Williams notes, it was taken on a heliotrope-like plant on various islands, also on some Leguminosae. This species is larger than the preceding and aeneous, not black in color.

***Longitarsus lunatus* Charles Waterhouse**

*Longitarsus lunatus* C. WATERHOUSE, 1877, Proc. Zoo. Soc. Lond., p. 81.

*Longitarsus lunatus* C. Waterhouse, MITCHLER, 1925, Zoologica, V, 20, p. 238.

The California Academy of Sciences has no specimens in its collection.

***Longitarsus galapagoensis* Van Dyke, new species**

Oval, quite convex above; piceous as to body, head, scutellum, fourth and following antennal segments, first and second pair of legs, and the tibia and tarsi of hind pair; the prothorax variable from entirely piceous to almost entirely castaneous. The holotype is castaneous with a V-shaped median and oblique lateral piceous spot, the elytra castaneous with sutural area and lateral margins somewhat piceous,

the general surface smooth and shining. Head smooth, eyes rather coarsely faceted, third antennal segment shorter than second or fourth, fifth longer than fourth, the following gradually more robust. Prothorax distinctly transverse, very finely, diffusely punctured. Elytra elongate oval, with prominent though rounded humeri; finely and rather sparsely punctured; wings fully developed. Length slightly over 2 mm., breadth somewhat less than a millimeter.

*Holotype* and numerous designated paratypes from a series of nineteen specimens collected by F. X. Williams on **Charles Island**, May 15, 1906. There is also one specimen collected in February, 1906 on Chatham Island by Mr. Williams; also four specimens collected by M. Willows, Jr., of the Templeton Crocker Expedition of 1932, two on Charles Island, April 25, 1932, and two on Indefatigable Island, May 5 and May 6, 1932.

This small and very distinctly marked species was compared with the type of *L. lunatus*, which is in the British Museum, and found to differ not only in color pattern, but in being larger, having the prothorax distinctly transverse while hardly wider than long in the other, in having the elytra broad at the shoulders and with them well developed while in the other elytra are narrowed at the shoulders and with them practically obliterated, also much broader across the middle. The wings are well developed in *L. galapagoensis* while apparently atrophied in *L. lunatus*.

### Family **BRUCHIDAE**

But two species of this family so far have been collected in the Galapagos Islands. They were both described by K. G. Blair.

#### **Spermophagus galapagoensis** Blair

*Spermophagus galapagoensis* BLAIR, 1928, Ann. Mag. Nat. Hist., ser. 10, I, pp. 678-679.

The California Academy of Sciences has two specimens of this species which have been carefully compared with the type. They were collected by M. Willows, Jr., of the Templeton Crocker Expedition of 1932, on Hood Island, April 20, 1932.

#### **Bruchus fuscomaculatus** Blair

*Bruchus fuscomaculatus* BLAIR, 1928, Ann. Mag. Nat. Hist., ser. 10, I, pp. 679-680.

No specimens of this species appear to have been taken except by the St. George Expedition of 1924. It is not represented in the California Academy of Sciences collection.



Family **ANTHRIBIDAE****Ormiscus** G. R. Waterhouse

*Ormiscus* G. R. WATERHOUSE, 1845, Ann. Nat. Hist., XVI, p. 37.

**Ormiscus variegatus** G. R. Waterhouse

*Ormiscus variegatus* G. R. WATERHOUSE, 1845, Ann. Nat. Hist., XVI, pp. 37-38.

*Ormiscus variegatus* G. R. Waterhouse, C. WATERHOUSE, 1877, Proc. Zoo. Soc., V, p. 82.

*Ormiscus variegatus* G. R. Waterhouse, LINELL, 1898, Proc. U. S. Nat. Mus., XXI, no. 1143, p. 268.

*Ormiscus variegatus* G. R. Waterhouse, MUTCHLER, 1925, Zoologica, V, no. 20, p. 238.

In the California Academy of Sciences there are three specimens of what is apparently this species. One is lighter in color than the type, somewhat immature, I would say, agreeing more with var. B. than with the type. It was collected on Gardner Island, near Hood Island, April 22, 1932, by M. W. Willows, Jr., of the Templeton Crocker Expedition of 1932. The second specimen was collected at Villamil, Albemarle Island, March 4-14, 1906, by F. X. Williams. The third specimen was collected on Abingdon Island, September 18-23, 1906, by F. X. Williams. The species has ample wings.

Family **CURCULIONIDAE**

Quite a number of weevils belonging to various subfamilies and tribes have been taken at different times on the Islands. Most of these have been collected in limited numbers too, which is not surprising considering that many of them are quite small. Judging from this I believe that there are many species still undiscovered in the Islands.

**Amphideritus cuneiformis** (G. R. Waterhouse)

Plate VII, figure 9

*Otiorynchus cuneiformis* G. R. WATERHOUSE, 1845, Ann. Nat. Hist., XVI, p. 38.

*Otiorynchus cuneiformis* G. R. Waterhouse, C. WATERHOUSE, 1877, Proc. Zoo. Soc., p. 82.

*Otiorynchus cuneiformis* G. R. Waterhouse, LINELL, 1898, Proc. U. S. Nat. Mus., XXI, no. 1143, p. 267.

*Otiorynchus cuneiformis* G. R. Waterhouse, MUTCHLER, 1925, Zoologica, 20, p. 238.

The original type of this species which should be in the British Museum, appears to have been lost. I looked for it very carefully while studying there, also had the assistance of the keepers, but without result. The California Academy of Sciences has two specimens collected by F. X. Williams on Chatham Island, one during July, 1906, the other and larger one, January 24-30, 1906; both agree absolutely with the Waterhouse description. These are the only specimens, I believe, that have been collected since Darwin's time, but these are sufficient to settle some points that have long been in doubt. They, of course, do not belong to the Old World genus *Otiorhynchus* but to the genus *Amphideritus* Schwarz, a well known South American genus, which is sufficiently characterized by the scrobes being lateral, broad behind, the prothorax without postocular lobes, the rostrum rather short and broad; the scape of the antennae rather long, passing the eyes; the elytra slightly broader than the prothorax; the scutellum visible between the elytra at base; and the front coxae contiguous but with a small postcoxal process. The first specimen had but recently emerged, for the deciduous pieces of the mandibles are still attached, broad at base, and sickle-shaped. This specimen is the smaller, 6 mm. long by 2.75 mm. wide. The second specimen, a somewhat worn individual with much of the scaling removed from both pronotum and disc of elytra, is larger, 8 mm. long by 4 mm. wide. In this second individual, as a result of the removal of much of the scaly covering, the pronotum is shown to be rather broadly, longitudinally impressed at middle and somewhat coarsely, irregularly punctured. The elytral striae in this second individual are rather well impressed as well as coarsely punctured and the intervals elevated and convex.

### **Pantomorus** Schonherr

*Pantomorus* SCHONHERR, 1840, *Genera et Species Curculionidum*, V. 2, Paris, p. 942.

*Aramigus* HORX, 1876, *Proc. Amer. Phil. Soc.*, XV, p. 93

This rather large genus which is so well represented in Mexico and Central America, differs from its parent stock, *Naupactus* Schonherr, which is dominant throughout much of South America, only by being wingless. The genus is a very polymorphic one. The typical forms as represented by the Mexican genotype, *P. albosignatus* Boheman, and the common and widely distributed species, *P. godmani* Crotch, now well established in western North America, are of rather moderate size and with a cylindrical prothorax. The species from the Galapagos Islands, for there are several rather closely related or slightly divergent

forms, are in general somewhat larger and have the prothorax more or less spherical like the Mexican species, *P. albicans* Champion. Champion (1911) in his treatment of Mexican species, has divided them into two groups:

1. Males without mucro on the inner edge of extremity of middle tibia.
2. Males with mucro on the inner edge of extremity of middle tibia.

To the first group, the more typical species belongs *P. albosignatus* Boheman, while to the second group belong such species as *P. albicans* Champion and those to be found in the Galapagos Islands.

In the Galapagos Islands, the genus is widely distributed and according to F. X. Williams the species in the adult stage are to be found on various plants, but preferably on the croton. In the various islands they have had a tendency to develop into more or less closely allied races and species. In the material at hand, I have a sufficient number of specimens to be able to separate about six species. A specimen from Hood Island is too rubbed to enable it to be properly characterized. All of the species in the Islands are quite variable as to size and color pattern, the usual coloration being gray or light brown produced by a rather closely appressed pile, with erect or suberect setae or long hair projecting above and a certain number of silvery white scales concentrated to form spots or maculations or placed in denser formation along the sides. In the majority of specimens the true scales are lacking while in others they are very evident, the most complete sealy pattern being shown in a large female specimen of typical *P. galapagoensis*, from Chatham Island. In this specimen, there are numerous elongate scales along the sides of the prothorax, placed vertically; somewhat more robust scales densely placed along the sides of the elytra, arranged obliquely; a series of elongate, more or less elliptical scales arranged in spots as follows: a small one at the base of the elytra near its middle and a series of three arranged in the manner of a broken lunule extending from the humerus to the suture near its center, a subapical macule, and a series of somewhat broader scales closely applied to the side pieces of the meso- and meta-sternum. The males are in general narrower than the females, less robust, with the legs longer and the front tibiae more arcuate towards the apex, the antennae apparently also longer, the prothorax more spherical with the base of the elytra more evidently elevated and carinate towards the suture, the abdomen also more flattened or broadly impressed towards the base.

**Pantomorus galapagoensis** Linell

Plate VII, figure 7

*Pantomorus galapagoensis* LINELL, 1898, Proc. U. S. Nat. Mus., XXI, no. 1143, p. 268.

*Pantomorus galapagoensis* Linell, MUTCHLER, 1925, Zoologica, V, no. 20, p. 238.

*Pantomorus galapagoensis* Linell, BLAIR, 1933, Ann. Mag. Nat. Hist., ser. 10, XI, p. 485.

Rather large and robust, piceous to rufopiceous, in fresh specimens rather densely clothed with a closely appressed pile of mixed light and dark brown or gray hairs, often with a silvery gloss, in addition with rather long, erect, fine hairs rather uniformly scattered over the elytra and in many specimens with patches of elongate silvery white scales arranged as three white spots of an interrupted lunule extending from the humerus to the suture near the middle, also along the side pieces of the meso- and metathorax. Head feebly convex, alutaceous, finely punctured and rugose and somewhat aciculate; rostrum broad, one and a half times as long as broad, flattened above, rugose and punctate, strigose at sides and with a sharply impressed longitudinal groove extending from the middle of frons to above the level of insertion of antennae; mandibles prominent with the supports to the deciduous pieces conspicuously projecting; eyes prominent, very convex, and obliquely set; antennae long, fully reaching to hind margin of prothorax, second funicular segment one-third longer than first. Prothorax one-fourth broader than long in female and but little broader than long in males, apex transverse, base feebly arcuate in females, distinctly sinuate at sides and with well defined median lobe in males, also rather finely margined in both sexes, sides broadly rounded, constricted in front and behind; disc very convex, alutaceous, fairly to coarsely rugose, sparsely punctured, sometimes aciculate and generally with a well impressed longitudinal line at middle. Elytra cordate, about two-sevenths longer than broad and three times as long as prothorax, convex, striae feebly impressed but strial punctures coarse but close and deeply impressed, intervals flat or feebly convex and generally almost twice as wide as striae and derm alutaceous and finely rugose. Legs long, front tibiae arcuate apically and coarsely serrate on inner margin in both sexes, middle tibia mucronate within at apex. Beneath with pile somewhat less dense than above. Length 10-14 mm., breadth 4.5-6 mm.

The males are in general narrower, with more spherical prothorax, somewhat concave abdomen, and with legs apparently longer. Linell was in error in stating that the males had the larger thorax.

Type, no. 1327, U.S.N.M. Linell had before him one male and four

females from Chatham Island (three collected by the *Albatross Expedition* in 1888 and two by Dr. G. Baur). One of these specimens, a paratype sent to the British Museum, I used for comparison with some of my specimens. The California Academy of Sciences has thirty-three specimens, thirty-two collected January 24–30, 1906, and February 21–24, 1906, by F. X. Williams on Chatham Island; also one collected April 15, 1932, by M. Willows, Jr., of the Templeton Crocker Expedition of 1932. This species, judged by the specimens which we have, is in general the largest and most robust of the Galapagos Islands species, also when fresh the most densely pilose and with the longest and finest erect hair. The color of the pile varies with the specimens, some being almost uniformly brown while others are varicolored, and in a limited number the maculation of silvery scales are very conspicuous.

### ***Pantomorus blairi* Van Dyke, new species**

Of moderate size, less robust than preceding species, piceous with appressed pile rather short and sparse, a unicolored brown or gray and not appreciably concealing the derm beneath, the erect hairs rather stiff and of moderate length, and well dispersed over the surface of the elytra. Head somewhat coarsely, closely punctured and rugose with the usual sharply impressed longitudinal line and generally the strigae, the rostrum and antennae with similar proportions to the preceding but the eyes a bit less prominent, less convex. Prothorax with proportions of *P. galapagoensis* but with disc rather finely and irregularly punctured and generally quite rugose, smoother in females and base generally more transverse in males. Elytra with base quite transverse, sides but slightly arcuate and convergent backwards and apex less acute. As a result of the sparse pubescence the derm of the disc is quite exposed, showing the strial punctures to advantage, which appear to be less coarse and closer together than they are in *P. galapagoensis*. Beneath with sparse pubescence. Length of holotype male 10 mm., breadth 5 mm., of allotype female, length 13 mm., breadth 7 mm. Three of the paratypes are much smaller.

*Holotype* male, allotype female, and two paratypes will be returned to the British Museum of Natural History. They are from a series of six specimens, kindly loaned to me for purposes of study by Dr. K. G. Blair. Two of the specimens will be retained. Three specimens are depauperized, much smaller than the others. All specimens were collected on **James Island**, February 20–22, 1925, by G. Bateson:

This species is in general slightly smaller and darker than *P. galapagoensis*, with head more distinctly punctured, the eyes less convex.

pronotum more definitely loosely punctured, the afterbody more parallel sided, the appressed pubescence sparser and the erect hairs more rigid. The usual color of the pile is of a uniform brown, gray in one or two, and in but one specimen are there a few silvery scales forming a small macule behind the base of the elytra though the scales of the meso- and metapleurae are quite evident in all specimens as usual.

***Pantomorus crockeri* Van Dyke, new species**

Small, piecous with legs somewhat rufous; body sparsely clothed with fine, rather short pile which is not closely appressed and which has the individual hairs somewhat curled and irregularly directed, the erect hairs of moderate length, stiff and rather oblique, scales absent except on the metapleurae where they are sparse and more hairlike than usual. Head coarsely punctured and rugose; eyes moderately prominent but widely separated by at least three times their own diameter; beak short and broad, as broad as long. Prothorax somewhat broader than long, coarsely and irregularly punctured and very rugose, with granules very conspicuous, and a well defined median longitudinal impression. Elytra nearly two-fifths longer than broad and three-fifths longer than prothorax, very convex, the declivity more precipitous than usual, the striae moderately impressed, striae punctures coarse and close, intervals feebly convex and about as wide as striae, the surface minutely punctured. Beneath rather sparsely clothed with fine hair. Length 7 mm., breadth 3.5 mm.

*Holotype*, a unique collected on **Tower Island**, March 25, 1935, by the Templeton Crocker Expedition of 1935, and deposited in the collection of the California Academy of Sciences.

This very distinct and stubby species has as its most characteristic features, its shortness and small size, its short rostrum, widely separated eyes, very granular pronotum, convex elytra, and irregularly inclined pubescence. I have named it after Templeton Crocker, a generous patron, who has added much to our knowledge of the Galapagos Islands.

***Pantomorus caroli* Van Dyke, new species**

Of moderate size, piecous or rufopiecous, body above rather densely clothed with closely appressed, regularly dispersed fulvous or gray pile, concealing to a great extent the derm beneath, and in addition provided with very short, stiff semierect hairs, irregularly dispersed over the elytra though most evident on the elytral declivity; and with scales generally absent above, only a few specimens showing them usually obliquely within and behind the humeri, but the scales on meso- and metapleurae present as usual but limited in number. Head

alutaceous, rather densely, finely punctured, often strigose at sides, flattened in front; eyes prominent, rather widely separated; rostrum broad but almost a third longer than broad, similarly sculptured to rest of head but with strigae more evident and with the usual sharply and deeply impressed longitudinal median groove running back to the occiput. Prothorax at least 5 mm. broader in female than male and barely broader than long in males, apex transverse or feebly emarginate at middle, base broadly feebly arcuate at middle in female, with a pronounced lobe at middle and strongly sinuate each side in male, sides broadly arcuate, somewhat constricted at base and apex in female, more definitely so in male and with the anterior and posterior margins also better defined; disc quite convex, finely diffusedly punctured, rugose and often distinctly alutaceous especially in males, and generally with a more or less observable median longitudinal impression. Elytra about a third longer than broad and three times as long as prothorax, somewhat transverse at base and with humeral angles well defined though rounded at apices especially in males, sides feebly arcuate and widening to posterior third thence more broadly rounded and convergent to apex; disc convex, striae not or feebly impressed, the strial punctures coarse, their own diameter apart, and deeply impressed, intervals generally flat and much wider than striae, general surface finely rugose and with minute punctures here and there. Beneath rather sparsely pubescent, legs as in related species. Length 6-13 mm., breadth 2.5-5.5 mm., the smaller measurements from depauperized specimens.

*Holotype*, allotype and several designated paratypes from a series of twenty-seven specimens in the California Academy of Sciences collection, all collected by F. X. Williams on **Charles Island**, October 3-15, 1905. There is also a single specimen before me, loaned by the British Museum which was collected by G. Bateson of the St. George Expedition, March 1925. The specimen is from Charles Island and is much denuded. There is considerable variation in size between individuals, several being quite small; there is also variation to a slight extent in color of pile, in degree of strial impression, and sculpturing of pronotum, most being quite rugose while two large females have the surface much smoother and shining. The males all have the prothorax quite spherical.

The main diagnostic characters of this species are the somewhat dense appressed pubescence, the short, dispersed yet evident erect hairs or setae, the (in general) finely rugose pronotum, and the fair size of the normal individuals. It appears to be most closely related to *P. galapagoensis*, differing primarily in having less dense pile, shorter

and sparser setae, and more coarsely sculptured pronotum; also the elytra are more transverse at base and the humeri more sharply angulate.

***Pantomorus conwayensis* Mutchler**

*Pantomorus conwayensis* MUTCILFR, 1938, Am. Mus. Novitates, no. 981, pp. 15-16.

Of moderate size, rufopiceous; sparsely clothed with short, gray, closely appressed pile which does not appreciably conceal the derm beneath; with a few short, curved setae, very obliquely set, hardly projecting above normal pile and only evident on elytral declivity; and in a limited number of cases with macules of elliptical shape and silvery scales, placed one on either side of the scutellum, a series of from three to four extending obliquely inwards from the humerus towards the suture and one on the sixth interval a third of the distance from the apex as well as forming a marginal patch along the outer side of the meso- and metasternal pleurites. Head alutaceous in front, rather densely punctured with broad, shallow, somewhat aciculate punctures, with the usual deep median longitudinal impression. Elytra almost a third longer than broad and about twice as long as prothorax, quite transverse at base, with well defined subangular humeri, the sides feebly arcuate and gradually expanded to posterior third; disc with striae slightly impressed, striae punctures coarse, close together and deeply impressed, the intervals as wide or slightly wider than striae, and flattened or feebly convex depending upon the degree to which the striae are impressed. Beneath sparsely pilose.

*Holotype* male and allotype, in the American Museum of Natural History.

In describing this species, Mutchler had before him, thirty-three specimens, collected either by the Williams' Galapagos Expedition of 1923 or by the Crocker Expedition of 1935. All of these were collected in Conway Bay, Indefatigable Island.

The California Academy of Sciences has the following specimens: one small paratype from Conway Bay, received from the American Museum of Natural History; two specimens collected March 24, 1925, at Academy Bay, Indefatigable Island, by the Templeton Crocker Expedition of 1925; two specimens collected May 6-7, 1932, by M. Willows, Jr., of the Templeton Crocker Expedition of 1932, and one collected October 25-28, 1905, by F. X. Williams, all labeled Indefatigable Island. Besides these are six other specimens, all badly rubbed, which were collected May 2 or 6, 1932, by M. Willows, Jr., of the Templeton



Crocker Expedition of 1932, on Indefatigable Island. One small specimen loaned by the British Museum, which was collected by G. Bateson of the St. George Expedition of February 16, 1925, is before me.

This species is best separated by its sparse pubescence and short, curved setae which are mainly confined to the elytral declivity. It is rather closely related to the species that follows:

***Pantomoris williamsi* Van Dyke, new species**

Very much like *P. conwayensis* in general appearance and in most essential features, having in particular the short sparse pubescence which does not appreciably conceal the derm. It differs, however, in having the erect setae which are rather short stiff hairs, quite evident, generally dispersed over the elytra and but little inclined, and in having the silvery scales which are quite elongate and hairlike, not elliptical as in the other species, assembled in various conspicuous macules in all of the specimens before me. These macules are arranged as follows: two somewhat vague ones at the base of the elytra, a series of three arranged in the form of an interrupted lunule from the humerus towards the suture, and a series of from two to three arranged transversely across the posterior third of the elytra, the outermost, the largest, placed on the sixth and seventh intervals. Length 9 mm., breadth 4.5 mm.

*Holotype* female and two paratype females, the first collected on **Albemarle Island**, April 15, 1906, by F. X. Williams, one at Cebes Settlement, Albemarle Island, April 24, 1906, collected by F. X. Williams, and the other at Iguano Cove, Albemarle Island, March 17-21, 1906, also by F. X. Williams. I also have before me three specimens from Banks Bay, Albemarle Island, April 10-17, 1906, collected by F. X. Williams, and two specimens on loan from the British Museum, collected in 1925, by G. Bateson, on Albemarle Island. These will also be considered as paratypes.

KEY TO GALAPAGOS ISLANDS SPECIES OF *PANTOMORIS* SCHONHERR

1. Erect hairs or setae rather long, fully as long as intervals are wide, quite dense and more or less uniformly dispersed . . . . . 2
- Erect hairs or setae somewhat short, generally sparse and as a rule more evident on elytral declivity . . . . . 4
2. The closely appressed pile of the elytra generally unicolored and sparse, allowing the brown derm to be readily seen beneath, true scales rarely seen . . . . . 3
- The closely appressed pile of the elytra generally varicolored, and dense,

- concealing the derm to a great extent, scales more or less evident (Chatham Island).....*R. galapagoensis* Linell
3. Rostrum much longer than broad; pronotum moderately, not coarsely rugose; pile of elytra light brown or gray and regularly inclined (James Island).....*P. blairi* Van Dyke
- Rostrum little longer than broad; pronotum coarsely rugose with evident granules; pile of elytra gray with individual setae much curved or curled and not regularly inclined (Tower Island).....*P. crockeri* Van Dyke
4. The appressed pile of elytra very short, fine and sparse, not concealing to any degree the brown derm beneath; macules of silvery scales generally present on elytra and very evident..... 5
- The appressed pile of elytra rather coarse and dense, concealing the derm to an appreciable extent, scaly macules rarely indicated on elytra, erect setae short and sparse on disc, longer, denser and more inclined on declivity (Charles Island). ....*P. caroli* Van Dyke
- 5 Short, erect setae sparsely dispersed over the elytra (Indefatigable Island) .. ....*P. concuayensis* Mutchler
- Setae hardly observable on disc of elytra, short and much inclined on elytral declivity, pile abundant (Albemarle Island). *P. williamsi* Van Dyke

### ***Gerstaeckeria galapagoensis* Van Dyke, new species**

Plate VII, figure 8

Medium sized, robust, black with rufous antennae; very densely clothed above with short, broad, varicolored scales, the majority dark brown, giving the basic color, the others varying from light brown to white, the latter generally assembled so as to give the distinctive color pattern. These scales are disposed as follows: about the eyes; on the pronotum, in the form of a short longitudinal line in front of the scutellum and a few spots on the disc, generally a pair near the center and several at the sides; and on the elytra as a lunate patch extending obliquely inwards from the humerus, and a slightly arched transverse patch, widest at center and sides, placed at the summit of the elytral declivity and extending from fourth interval on one elytron to the fourth on the opposite elytron. The scaling on the underside and legs is somewhat less dense than above. Head very coarsely, densely punctured above, the punctures extending on to the sides of the rostrum but becoming finer and more widely spaced toward the apex with each puncture on head and base of rostrum supporting a scale which is rather broad on occiput and narrower and more upright between the eyes, also in general a lighter brown or dirty white about the eyes; eyes separated in front by slightly more than the diameter of a single eye, a small fovea between; the rostrum about as long as head, feebly arched, carinated above, constricted in front of eyes and feebly nar-

rowed about middle. Prothorax about one-fifth broader than long, base transverse, apex over one-fourth narrower than base, broadly arcuate, the lobe covering base of head, sides arcuate from base forward to beyond middle, thence narrowed and feebly constricted before apex, disc convex, densely and coarsely punctured, each puncture supporting a scale. Elytra more a fifth longer than broad and about two and a half times as long as prothorax, without posthumeral process, the sides evenly arcuate from base to posterior third then gradually narrower and somewhat sinuate to the somewhat extended apex; disc very convex, the declivity almost vertical, striae broad and well impressed, the striae punctures very coarse, separated by one-half their own diameter, intervals as wide as striae, convex and finely and rather densely punctured, all punctures supporting a scale as elsewhere above and all intervals equally scaly. Beneath rather coarsely, densely punctured. Legs with femora unarmed, clothed with light and dark scales, which are generally arranged in a somewhat annulated manner on the outer face, the third tarsal segment very broad, lobed, much wider than second. Length, without rostrum, 7-8 mm., breadth 3.5-4 mm.

*Holotype* and designated paratypes from a series of forty-six specimens, collected by F. X. Williams on **Abingdon Island**, September 18-23, 1906. This species would probably fall in the subgenus *Copuntia* Pierce and somewhere near *G. cruciata* Champion according to Pierce's (1889) key.

Besides the rather large Abingdon Island series of specimens of *Gerstaeckeria* in the collection of the California Academy of Sciences, there are specimens from several of the other islands of the Galapagos Archipelago. These all possess the basic characters and general scale color pattern indicated in *G. galapagoensis* though those from certain islands seem to possess in addition, and in spite of their variability, certain definite peculiarities which I think entitles them to a name as subspecies, though nothing more.

***Gerstaeckeria galapagoensis barringtonensis* Van Dyke,**  
new subspecies

This form apparently differs from the more typical form by being in general slightly smaller; by having the prothorax barely broader than long, the sides well rounded and with the greatest breadth in front of the middle and almost straight behind and convergent to base; and by having the disc of both pronotum and elytra as seen from the side, more convex, the humeral angles more rounded, and the striae

punctures of the elytra more sharply defined. Length 6 mm., breadth 3 mm.

*Holotype* and several designated paratypes from a series of thirteen specimens, collected on **Barrington Island**, July 4-10, 1906, by F. X. Williams.

***Gerstaeckeria galapagoensis hoodensis* Van Dyke, new subspecies**

This form is about the same size as the preceding and also differs from typical *G. galapagoensis* in having the prothorax but slightly broader than long, with sides but feebly arcuate; the elytra with the sutural interval depressed, the others very convex, and the striae punctures sharply defined.

*Holotype* and four paratypes collected on **Hood Island**, by F. X. Williams, on the following dates: two in January, 1906, two on June 23-30, 1906, and one on February 1-14, 1906.

***Gerstaeckeria galapagoensis seymourensis* Van Dyke, new subspecies**

The specimens of this subspecies are all, unfortunately, almost completely denuded of scales. They are the largest of any of the races, have the prothorax one-sixth broader than long, with the sides well rounded and broadest at middle, the disc somewhat flattened, elytra elliptical, one-third longer than broad, and with the disc quite flattened as seen from the side but not when viewed from behind, and the intervals equally elevated. The size and elongated body chiefly distinguish it. Length 9 mm., breadth 4 mm.

*Holotype* and three paratypes, three collected on **South Seymour Island**, November 22, 1905, and one July, 1906, by F. X. Williams. I have also associated with these a single specimen collected on Indefatigable Island, October 25-38, 1905, by F. X. Williams. It cannot be distinguished from the others.

All of the members of the genus *Gerstaeckeria* are cactus feeding. We have numerous species in the southern part of the United States, chiefly in the semiarid Southwest, in Mexico and the West Indies, I know of none that have been described from South America though I feel that they must be found somewhere along the more desert parts of the West Coast. They have no functional wings.

***Geraes batesoni* Blair**

*Geraes batesoni* BLAIR, 1933, Ann. Mag. Nat. Hist., ser. 10, 1X, pp. 485-486.

No specimens have been taken by any of the Academy's expeditions

nor by any expeditions previous to the St. George Expedition which furnished Blair's specimen.

**Lembodes subcostatus** Van Dyke, new species

Plate VII, figure 3

Small, elongate and subdepressed, black opaque, more or less covered with a chalky indumentum which gives the insect a clouded gray and brown appearance, and with stubby scales arranged in series or tufts over the upper surface and more or less regularly arranged on the legs. Head partly concealed by overhanging pronotum and with a few stubby erect scales placed between the eyes and on base of rostrum; antennae rufous. Prothorax almost a third longer than broad, apex in the form of a lobe, notched at middle and overhanging the head, base transverse, sides almost straight or very feebly arcuate to beyond middle where they are suddenly narrowed as they merge with the margins of the shovel-like apical lobe; disc rather irregularly convex behind, more flattened in front with the erect, brown, stubby scales scattered over the base, arranged in the form of four tufts one on either border near the middle and one on either side of the middle of disc, and in a denser series in arched formation just back of apical margin, as well as a few scattered behind this series. Elytra about twice as long as wide and twice as long as prothorax, base transverse with humeral angles extending slightly forward, sides almost straight and feebly diverging to beyond the middle, thence arcuate, narrowed and sinuate at apical fourth and continued on to the rather broad subtruncate apex which is feebly notched at suture; the disc convex, somewhat flattened suturally and with a series of three feeble longitudinal costae on either side which are surmounted and more definitely outlined by series of the suberect stubby brown and gray scales, the costae placed one along the side margin, one somewhat above and one midway between this and suture, this last diverging from the suture as it passes backwards, a few scales also placed along the suture. Beneath with surface concealed by gray indumentum, in addition to a few scales scattered over second ventral and arranged in transverse rows on the third and fourth ventral segments. Legs gray, somewhat annulated with black on outer surface and rather densely set with the more or less erect scales which are larger and spoon shaped on the tibiae. Length 4.5 mm., breadth 1.75 mm.

*Holotype* and two paratypes, collected as follows, the holotype from **Duncan Island**, November 1, 1905, a second specimen, also from Duncan Island, January 1-17, 1905, and the third from Iguano Cove, Albe-marle Island, March 17-21, 1906, all by F. X. Williams.

Five other species have been described previously: *L. solitarius* Boheman, the type species from the West Indies; *L. ululu* Chevrolat from Santo Domingo; *L. trux* Champion from Guatemala; *L. furci-collis* Chevrolat from Colombia; and *L. albo-signatus* Chevrolat from Chile. The species *Lembodes subcostatus* has been compared with the type of *L. trux* and found to be very different, being larger, less parallel, and with a lobed not truncate prothorax, as well as differing otherwise, and it apparently does not agree with the descriptions of the other species.

### **Anchonus galapagoensis** (G. R. Waterhouse

*Anchonus galapagoensis* G. R. WATERHOUSE, 1845, Ann. Nat. Hist., XVI, p. 39.

*Anchonus galapagoensis* G. R. Waterhouse, C. WATERHOUSE, 1877, Proc. Zoo. Soc., V, p. 82.

*Anchonus galapagoensis* G. R. Waterhouse, LINFELT, 1898, Proc. U. S. Nat. Mus., XXI, no. 1143, p. 268.

*Anchonus galapagoensis* G. R. Waterhouse, MÜTCHLER, 1925, Zoologica, V, no. 20, p. 238.

*Anchonus galapagoensis* G. R. Waterhouse, BLAIR, 1933, Ann. Mag. Nat. Hist., ser. 10, XI, p. 485.

Outside of the specimens collected by Charles Darwin and described as above by G. R. Waterhouse, there are only two specimens that I know of that have been collected since in the Archipelago, one listed by Blair from the type locality, James Island, and one in the California Academy of Sciences collection, collected on James Island between December 22, 1905, and January 5, 1906, by F. X. Williams. This last specimen has been carefully compared with the type. The genus *Anchonus* Schonherr is a large one, widely distributed throughout the warmer parts of the New World, being found in Mexico, Central and South America, and the West Indies. One specimen has even been taken in the South Pacific.

### **Dryotribus mimeticus** Horn

*Dryotribus mimeticus* HORN, 1873, Proc. Am. Phil. Soc., XIII, p. 433.

*Dryotribus mimeticus* Horn, BLAIR, 1933, Ann. Mag. Nat. Hist., ser. 10, XI, p. 486.

*Thalattodora insignis* PERKINS, 1900, Fauna Hawaiiensis, vol. 2, p. 146

Three specimens of this species were taken on Narborough Island by C. L. Collenette of the St. George Expedition. Blair states that this widespread species is represented in the British Museum of Natural

History collection by specimens from Florida, the West Indies, China, western Australia, and Hawaii. I have seen specimens also from the Marquesas Islands. It is a strand inhabiting species so no doubt owes its wide distribution to this fact. No specimens of this species were collected in the Galapagos Islands by the California Academy of Sciences expedition.

***Macrancylus gracilis* Van Dyke, new species**

Small, linear and subcylindrical, smooth and shining, rufous with base of head piecous, head parallel sided or feebly convergent forwards to beyond eyes, occiput smooth with a feeble transverse impression demarking it in front, the frons alutaceous and rather coarsely and regularly punctured, the punctures separated by at least their own width; eyes small, lateral, much flattened, hardly projecting beyond side margin; rostrum about as long as head proper, slightly narrower at base than head, with straight sides feebly convergent forwards, the supper surface with punctures continuous with those of head but gradually finer; antennae rufous but with club very light colored, a yellowish white. Prothorax at least twice as long as broad, sides rounded at base, straight and gradually convergent forwards; disc alutaceous with punctures somewhat coarser than on head, rather regularly placed and about their own diameter apart. Elytra over three times as long as broad and one-third longer than prothorax, as broad at base as base of prothorax, with base transverse, the humeri rounded, sides straight and parallel until near apex where they become rounded, disc striatopunctate, the striae feebly impressed, punctures rather coarse and close together, almost contiguous in places, the intervals flat, as wide as striae and crenulate as a result of being indented by punctures. Beneath alutaceous, with punctures rather regularly yet widely distributed, the after-body piecous. Length 3 mm., breadth 5 mm.

*Holotype*, a specimen collected on **Abingdon Island**, in September, 1906, by F. X. Williams. Nine other specimens from Abingdon Island collected in September 18-23, 1906, by F. X. Williams have been designated as paratypes.

This species has been carefully compared with specimens of *M. linearis* Le Conte, from Florida and the West Indies and with *M. immigrans* (Perkins) from Hawaii, the two other species in the genus, and found to be more narrowed, shining, and in general more graceful than either, with the head including rostrum a bit narrower, the eyes less prominent but otherwise with about the same proportions; the

puncture somewhat finer (in *M. linearis*), coarse and close while in *M. immigrans* they are rather coarse but not close; the prothorax more narrowed than in either of the others as is also the general body, alutaceous, with punctures finer and better separated; the elytra smoother, intervals finer and more flattened, in others more or less convex, striae punctures also much finer and as a result the striae themselves less deeply impressed. The general color is also lighter, a clearer red, not rufopiceous as in the others. The distribution of these three species is somewhat suggestive of that of the species previously mentioned.

### **Neopentarthrum Mutchler**

*Neopentarthrum* MUTCHLER, 1925, Zoologica, V, no 20, p 231.

The California Academy of Sciences possesses a paratype of *Neopentarthrum towerensis* Mutchler, kindly donated by Mr Mutchler, also a single specimen collected on Tower Island (Darwin Bay), June 16, 1932, by M Willows, Jr., of the Templeton Crocker Expedition of 1932, which has been compared with the type. In addition the Academy possesses specimens of several other species, differing greatly from the above, from other islands. These will be described later on.

### **Neopentarthrum towerensis Mutchler**

*Neopentarthrum towerensis* MUTCHLER, 1925, Zoologica, V, no 20, pp 231 232, fig. 45.

*Neopentarthrum towerensis* Mutchler, BLAIR, 1933, Ann. Mag. Nat. Hist., ser. 10, XI, p 468

Besides the above, Blair lists one specimen from Franklin Lake, as having been taken by the St. George Expedition. The California Academy of Sciences specimens have been mentioned previously.

### **Neopentarthrum cunicollis Van Dyke, new species**

Of the same size and general proportions as *N. towerensis* but with the prothorax well rounded and broadest close to the base, the sides almost straight and convergent to apex with hardly a perceptible interruption by the feeble post-apical constriction, thus forming a wedge-shaped body; the elytra with striae rather deeply and sharply impressed on the disc, the punctures clear cut, close together, and to a great extent confined to striae, indenting the intervals but little thus the latter are more regular, less crenulate throughout. The punctuation of the pronotum and underside and other characters are practically the same as in *N. towerensis*.



*Holotype*, a unique collected on **Duncan Island**, December 1, 1905, by F. X. Williams. With this species I have associated another specimen, not differing morphologically as far as I can see except in having the elytral striae less sharply impressed and the punctures a bit larger thus nicking the intervals to a greater extent. This specimen which was collected near Iguano Cove, Albemarle Island, May 21, 1932, by M. Willows, Jr., of the Templeton Crocker Expedition of 1932, I would consider but a variety of *N. cunicollis*.

***Neopentarthrum mutchleri* Van Dyke, new species**

Of about the same size and proportions as *N. towerensis*, piceous or slightly rufopiceous beneath with legs and antennae rufous. Head alutaceous and with fine sparse punctures; the rostrum slightly longer and with basal portion narrower; the eyes more flattened, not protruding at all beyond side margins. Prothorax feebly broader than long, with sides evenly and well rounded, very narrowly constricted at base and more broadly so at apex; disc as regularly but slightly more finely punctured, the post apical transverse impression distinct sharply demarking a collar; elytra about twice as long as broad, the sides feebly but regularly arcuate from transverse base to posterior fourth where regularly rounded to apex; the disc with striae not defined but the stria punctures distinct and serially arranged while the finer interstria punctures are only observable here and there. Beneath with the few punctures finer than in *N. towerensis*.

*Holotype*, a specimen collected on **Abingdon Island**, September 18-23, 1906, by F. X. Williams. Three other specimens from Abingdon Island, collected at the same time as the above, have been designated as paratypes. A fourth specimen, which I have associated, is from Indefatigable Island, collected October 25-26, 1905, by F. X. Williams. It is somewhat narrower and generally less robust than the Abingdon specimens but with identical sculpturing. I cannot see that this specimen is anything more than a variety. The Abingdon specimens, I am naming after my good friend, A. J. Mutchler, former curator of insects in the American Museum of Natural History.

***Neopentarthrum glabrum* Van Dyke, new species**

Somewhat narrower than *N. towerensis*, with head and pronotum distinctly alutaceous, the elytra elliptical and practically smooth, the sculpturing obscure at most and of a black color, with antennae and legs rufous. Head feebly, sparsely punctured behind, more coarsely and closely so in front and on base of rostrum, the latter about as long

as head and broad, especially in front; the eyes feebly projecting beyond side margin of head. Prothorax with sides broadly rounded in type, less so in paratype, narrowly constricted at base and broadly narrowed and sinuate towards apex; the disc with punctures rather fine and well spaced, the anterior transverse impression vague, not forming a well defined collar though the apex is distinctly narrowed. Elytra elliptical, twice as long as broad, sides evenly arcuate from transverse base to posterior fourth, then more definitely rounded to apex; the disc moderately convex, smooth and somewhat shining, the striae obliterated and strial punctures likewise except those near the suture which are small and feebly indicated. Beneath smooth in front, with a few fine and sparse punctures on metasternum and somewhat coarser and more numerous punctures on last three abdominal segments. Length 3 mm., breadth 1 mm.

*Holotype* and one paratype, the first collected on **Hood Island**, January, 1906, and the second on Abingdon Island, September 18-23, 1906, both by F. X. Williams. This comparatively smooth species is most closely related to *N. mutchleri* but readily separated by its black color, pronounced elliptical elytra, and practical absence of elytral sculpturing. In spite of one of the specimens coming from Abingdon Island, the home of *N. mutchleri*, it agrees absolutely with the type of *N. glabrum* and not with the former.

#### KEY TO SPECIES OF NEOPENTARTHUR MUTCHLER

1. Elytra with sides straight and parallel in basal two-thirds, the elytral striae sharply impressed and regularly punctured . . . . . 2
- Elytra somewhat elliptical, that is with sides more or less arcuate throughout, striae either vague or not impressed . . . . . 3
2. Prothorax widest at about the middle . . . . . *N. towerensis* Mutchler
- Prothorax widest near the base. . . . . *N. cunicollis*, new species
3. Elytral striae vaguely impressed but strial punctures distinct though shallowly impressed and somewhat regularly arranged . . . . .
- Elytra smooth without striae and with only a vague puncture here and there . . . . . *N. glabrum*, new species

#### Family PLATYPODIDAE

##### *Platypus santacruzensis* Mutchler

*Platypus santacruzensis* MUTCHLER, 1925, Zoologica, V, no. 20, pp. 232-233, fig. 24.

Recently while going over some duplicate material, I found what is presumably a second specimen collected on South Albemarle Island,

August 20, 1906, by F. X. Williams. This gives the California Academy of Sciences a representative of this species.

### Family **SCOLYTIDAE**

#### ***Pycnarthrum insulare*** Blair

*Pycnarthrum insulare* BLAIR, 1933, Ann. Mag. Nat. Hist., ser. 10, XI, p. 487.

Besides the four paratypes cited by Blair which are in the California Academy of Sciences collection and which were collected: the Tower Island specimens, September 14, 1905, and the Hood Island specimens, January, 1906, both sets by F. X. Williams, the Academy also possesses five more specimens from Tower Island and five more from Hood Island, same data as above, as well as a series of fifty-five specimens collected on Albemarle Island, March 4-14, 1906, by F. X. Williams. These insects are stated by Dr. Williams to breed in mangrove seeds.

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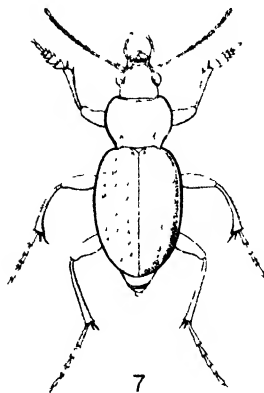
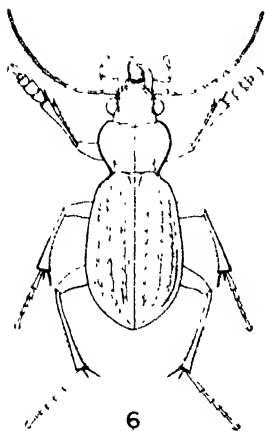
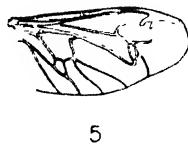
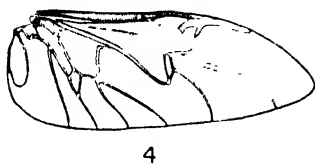
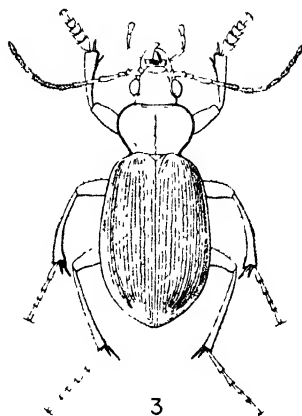
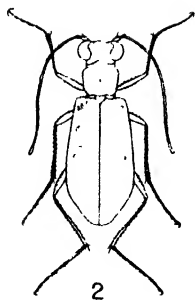
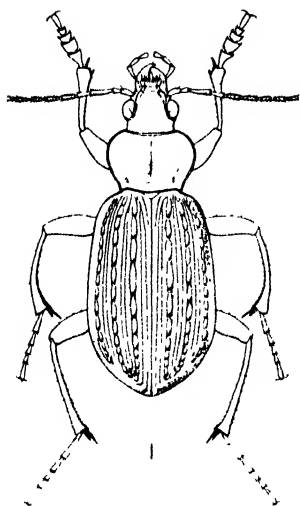
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# PLATE 1

1. *Calosoma howardi* Linell
2. *Cicindela galapagoensis* W. Horn
3. *Calosoma darwinia*, new species
4. Right wing of *Calosoma howardi* Linell
5. Right wing of *Calosoma darwinia*, new species
6. *Calosoma galapageium* Hope
7. *Calosoma linelli* Mutchler





## PLATE 2

1. *Scarites galapagoensis* Linell
2. *Selenophorus obscuricornis* (G. R. Waterhouse)
3. *Scarites williamsi*, new species
4. *Feronia duncani*, new species
5. *Feronia galapagoensis* G. R. Waterhouse
6. *Feronia calathoides* G. R. Waterhouse
7. *Agonum darwini*, new species
8. Prothorax of *Agonum darwini*, new species
9. Prothorax of *Agonum chathamii*, new species
10. *Agonum albemarti*, new species

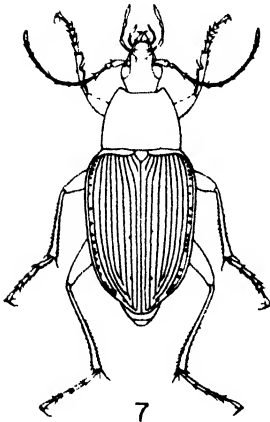
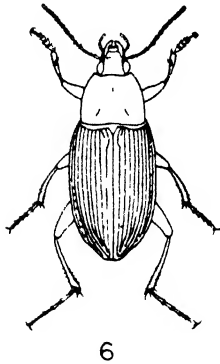
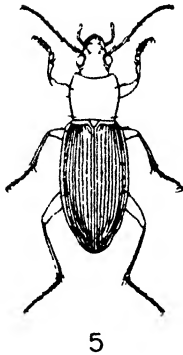
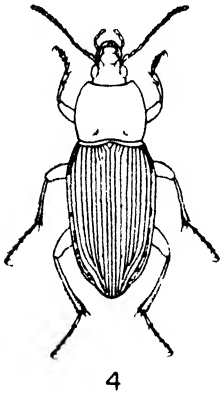
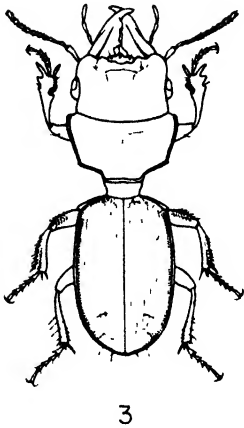
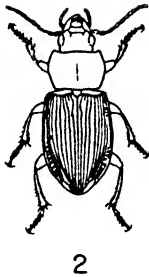
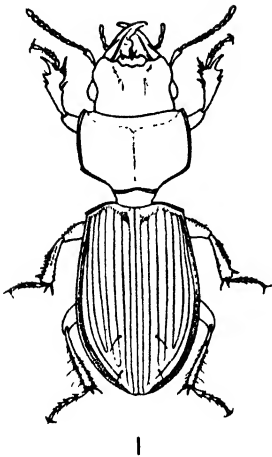
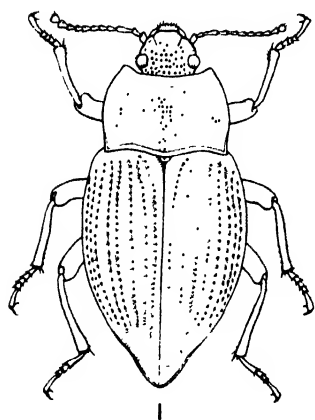
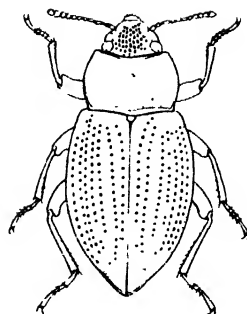


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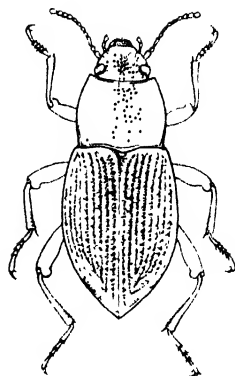
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2. *Stomion helopoides* G. R. Waterhouse
3. *Stomion cribricollis*, new species
4. *Stomion longulum*, new species
5. *Stomion laevigatum* G. R. Waterhouse
6. *Stomion linnelli* Blair
7. *Stomion longicornis*, new species
8. *Stomion rugosum*, new species



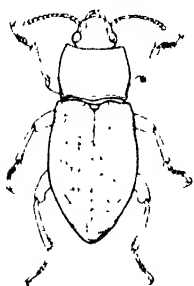
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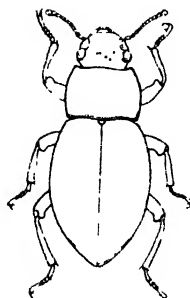
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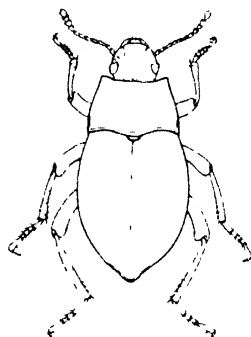
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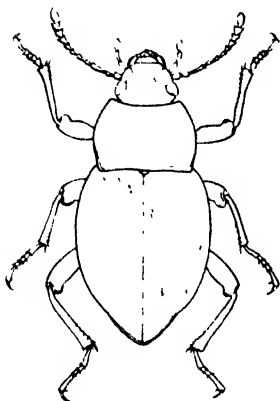
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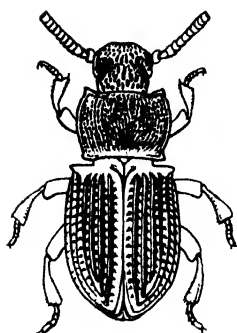
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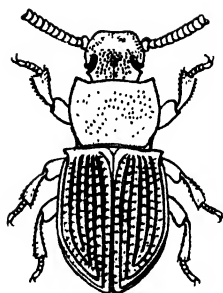
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PLATE 4

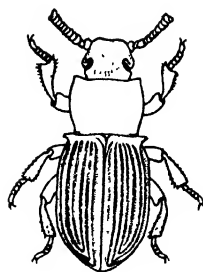
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2. *Ammophorus galapagoensis subpunctatus*, new subspecies
3. *Ammophorus galapagoensis laevis*, new subspecies
4. *Ammophorus cooksoni* C. Waterhouse
5. *Ammophorus obscurus* G. R. Waterhouse
6. *Ammophorus bifoveatus* G. R. Waterhouse
7. *Ammophorus abingdoni*, new species
8. *Ammophorus insularis* Boheman



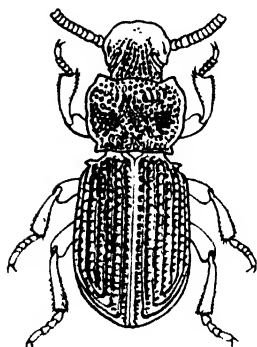
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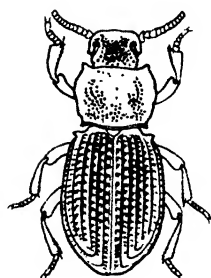
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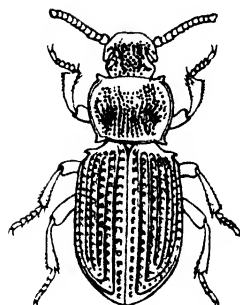
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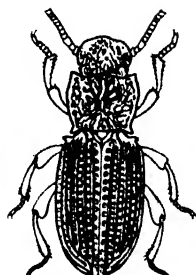
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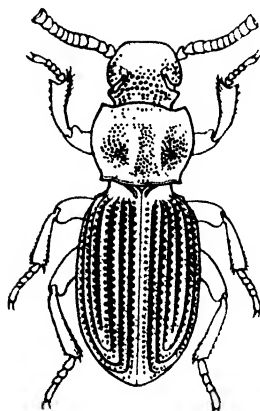
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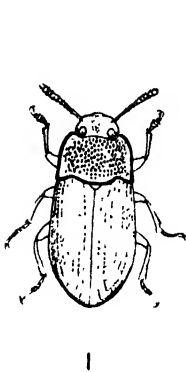
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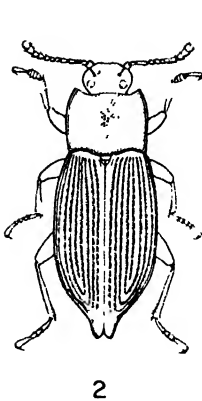
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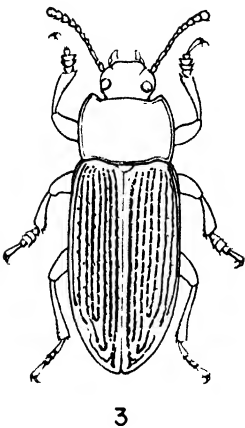
- 1 *Pedonocees uenmani*, new species
2. *Pcdonocees caudatus*, new species
3. *Pedonocees bauri* Linell
4. *Pedonocees galapagoensis* G. R. Waterhouse
5. *Pedonocees spatulatus*, new species
- 6 *Pedonocees costatus* G. R. Waterhouse
7. *Pedonocees pubescens* G. R. Waterhouse
8. *Pedonocees lugubris* (Boheman)
9. *Pedonocees barringtoni*, new species



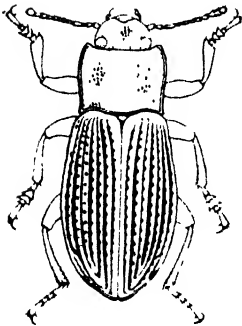
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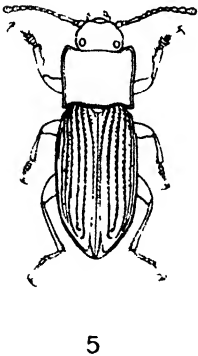
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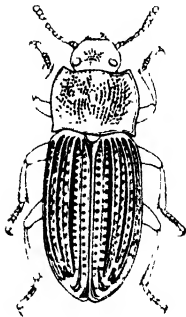
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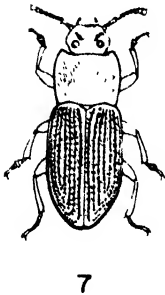
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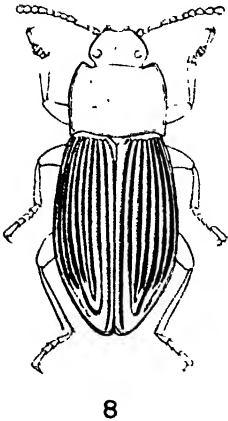
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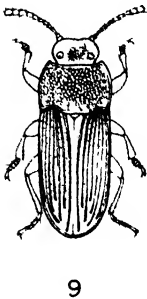
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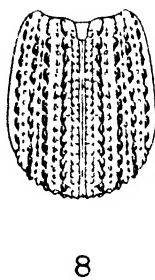
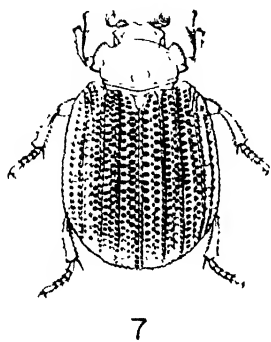
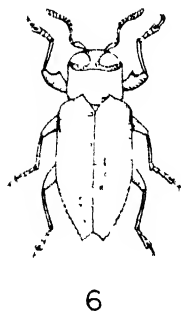
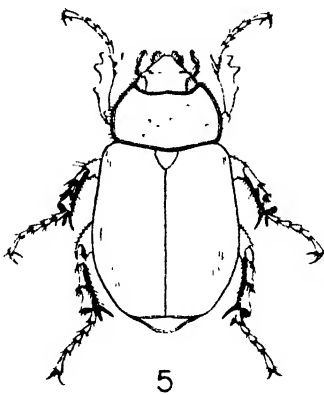
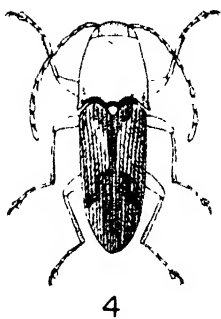
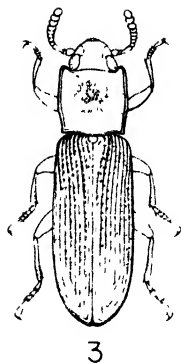
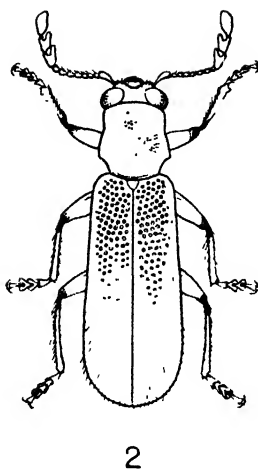
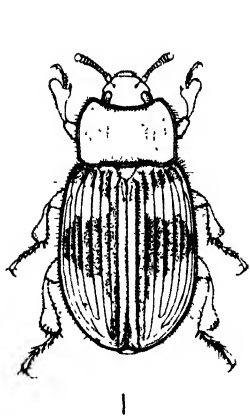


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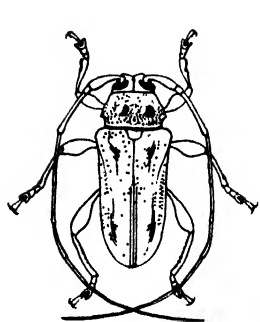
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1. *Phaleria manicata* Boheman
2. *Pelonium longfeldi* Blair
3. *Rhacius costipennis* Blair
4. *Conoderus galapagoensis*, new species
5. *Neoryctes galapagoensis* (G. R. Waterhouse)
6. *Chrysobothris williamsi*, new species
7. *Trox galapagoensis*, new species
8. Elytra of *Trox seymourensis* Mutchler

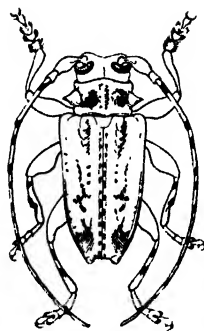


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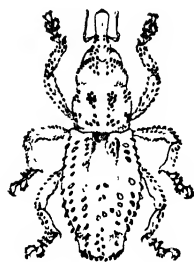
1. *Leptostylus galapagoensis*, new species
2. *Acanthoderes galapagoensis* Linell
3. *Lembodes subcostatus*, new species
4. *Estola galapagoensis* Blair
5. *Strongylaspis krapelini* Lameere
6. *Acryson galapagoensis* Linell
7. *Pantomorus galapagoensis* Linell
8. *Gerstaeckeria galapagoensis*, new species
9. *Amphidcritus cuneiformis* (G. R. Waterhouse)



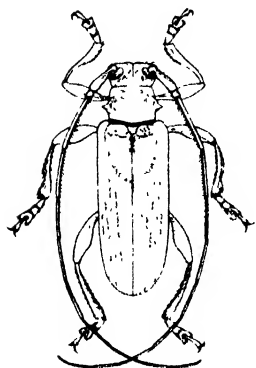
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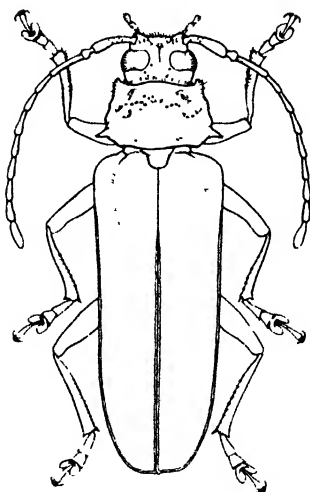
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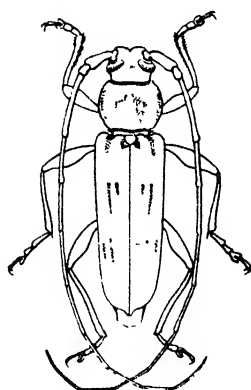
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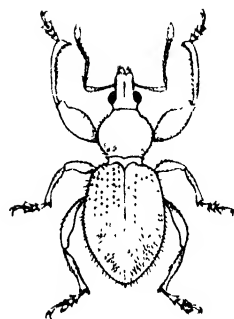
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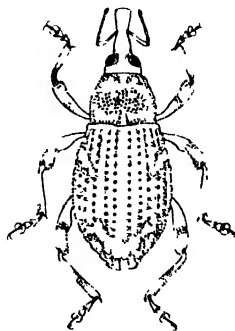
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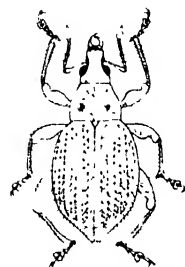
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# A Geological Reconnaissance of Panama

BY  
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SAN FRANCISCO  
CALIFORNIA ACADEMY OF SCIENCES  
1956

OCCASIONAL PAPERS NO. XXIII  
OF THE CALIFORNIA ACADEMY OF SCIENCES  
Issued March 2, 1956

COMMITTEE ON PUBLICATION

DR. ROBERT C. MILLER, *Chairman*

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DR. EDWARD L. KESSEL, *Editor*

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# A Geological Reconnaissance of Panama

## INTRODUCTION

### SOURCES AND ACKNOWLEDGMENTS

This paper is based primarily on field work conducted by the author in the Republic of Panama between the years 1920 and 1949. Much of the exploration was carried on as an independent undertaking, pursued as time and opportunity offered. But of the period involved, seven years were spent in the service of the Sinclair Panama Oil Corporation, to whose parent companies, the Sinclair Oil Company and the Cities Service Company, the writer is indebted for the privilege of publishing material from the files, including not only his own work, but that of a previous party which covered a considerable part of the area in 1917 and 1918, as well as material derived from well logs, and results of paleontological examinations of collections from wells and from the field. In this connection, gratitude is especially due to Mr. F. A. Bush, Dr. W. B. Heroy, and the late Mr. A. C. Veatch.

The Gulf Oil Company has given generously of its store of information acquired over years of exploration and drilling in the Garachiné area of Darien Province. The Panama Corporation of Canada, Ltd., through Messrs. Beresford, Benagh, and Retallac, furnished maps and information; and other members of its staff gave advice and assistance in the study of Panama's most famous mine, the Espíritu Santo, of Cana in Darien Province. The officials and staff of the United Fruit Company and its subsidiary, Chiriquí Land Company, have rendered innumerable services of many kinds. Gratitude is especially due to Mr. H. S. Blair, former manager; Mr. Rudolph Jensen, one-time chief engineer; and Mr. F. W. Genuit, once special agent; all of the Chiriquí Land Company at Puerto Armuelles.

Many officials of the Republic of Panama have offered encouragement and assistance, including two presidents of the Republic, Dr. Harmodio Arias Madrid, president from 1932 to 1936, whose letter to local officials greatly facilitated the work during this period; and the late Don Domingo Dias Arosemena, president in 1948 and 1949, to whom the writer is indebted for the opportunity to study in detail the aerial photographs of the Republic.

From various members of the staff of the Panama Canal, particu-

larly the late Mr. R. Z. Kirkpatrick, for many years Chief of Surveys of the Bureau of Maintenance and Operations, there has been received much valuable information and assistance. Dr. D. F. MacDonald, late Geologist of the Panama Canal, and his successor, Mr. T. F. Thompson, placed much information at the writer's disposal, and offered opportunities to visit areas otherwise inaccessible.

Dr. T. W. Vaughan, of the United States Geological Survey, furnished the results of a preliminary examination of fossils submitted to him jointly by Mr. A. A. Olsson and the writer. Dr. G. D. Harris of Cornell University and Dr. H. N. Coryell of Columbia University generously undertook the identification of fossil collections; and other paleontologists, notably Dr. Katherine Van Winkle Palmer, G. D. Tash, and A. D. Brixey, Jr., furnished fossil identifications and offered useful suggestions. Dr. L. G. Hertlein of the California Academy of Sciences and Mr. C. C. Church, research associate of the same institution, and Dr. Hans Thalman of Stanford University checked the nomenclature of the foraminifera identified from well cuttings, and also the mollusks collected in the field. Dr. E. R. Dunn of Haverford College generously took time to collect rock specimens and make geologic observations in the highest part of the Azuero Peninsula, a region from which no other information was available.

However, more than to any other individual, the writer is indebted to A. A. Olsson for advice, encouragement, and active assistance in field and office.

The Lake Nicaragua, Panama, Bogotá, and Barranquilla sheets of the 1:1,000,000 map published by the American Geographical Society of New York, the Lake Nicaragua, Panama Canal, Peninsula of Azuero, and Cape Corrientes sheets of the World Aeronautical Chart, published by the Aeronautical Chart Service of the United States Air Force, have furnished the topographic basis for the maps of the land areas, supplemented by various maps of surveys by the Department of Maintenance and Operation of the Panama Canal, and by maps of the various oil, mining, and fruit companies listed above. In some areas, where no such surveys have been made, the writer has made his own.\*

The positions of the isobaths have been taken from the 1:5,000,000 "Map of the Americas" of the American Geographical Society of New York, and from many of the charts issued by the Hydrographic Office

\*Discrepancies between elevations as given in the text and as shown on the map are due to recent information arriving too late for inclusion in the map. The elevations cited in the text are taken from the World Aeronautical Charts published by the Aeronautical Chart Service, U. S. Air Force, Washington, D. C., as follows

769. Panama Canal, Canal Zone-Colombia-Panama. 8th edit revised, December, 1953.

829. Cape Corrientes, Colombia-Panama. 7th edit, April, 1954.

830. Peninsula of Azuero, Costa Rica. 5th edit, August, 1953.

of the United States Navy, of which charts numbers 2015a, 5011a, 5013a, and 1176 have been particularly useful for areas outside the continental shelf. In addition, the writer secured from the Hydrographic Office, photostats of the "smooth sheets" for most of the Pacific coast and for the Caribbean coast of the Province of Bocas del Toro, and adjacent shores of Costa Rica. Since the "smooth sheets" contain all the soundings instead of the three to five per cent usually shown on the Hydrographic Charts as issued, an enormous amount of detail is made evident which would be unsuspected from a study of the Hydrographic Office charts. Canal Zone geology as shown is adapted from the published maps of MacDonald (1915) and Jones (1950) with some slight modifications.

In 1934, the writer, at the request of Professor Charles Schuchert, submitted to him for publication in his "Historical Geology of the Antillean-Caribbean Region," a geologic map of Panama which had been compiled by the Geology Department of the Sinclair Oil Company some fifteen years earlier. A much-reduced and altered version of the map was included in Schuchert's volume. Since that time two maps, sponsored by the Geological Society of America and the United States Geological Survey, have been published. All these maps are on a scale too small to furnish more than a generalized idea of Isthmian geology. It is hoped that the map presented herewith may be of use to persons interested in the subject, who desire greater detail.

Geologists who have worked in the rainy tropics know the difficulties imposed by heavy vegetation, deep weathering of the rocks, and unfavorable climate. These difficulties are encountered in the most extreme form in Panama. In addition, difficulties in correlation due to lithologic uniformity, and overlapping of fossil species that in other regions are distinctive, make it difficult and in many cases impossible to draw contact lines. Even in the Canal Zone, which has received many times as much attention as any other part of Panama, there are still doubtful contacts and correlations. The writer can only hope that the inevitable errors on the map will not prove too embarrassing.

#### GENERAL FEATURES

The Republic of Panama lies between parallels  $7^{\circ} 9'$  and  $9^{\circ} 37'$  N., and meridians  $77^{\circ} 9'$  and  $85^{\circ} 1'$  W., with a maximum east-west extension of about 390 miles and a maximum north-south extension of about 170 miles. Its area is about 29,000 square miles. Of this area probably less than half is permanently inhabited. Approximately one-half the country is above the 1,000-foot contour, but perhaps ninety per cent of the population live below it. All the provincial



capitals and also the national capital are below the 100-meter (328-foot) contour. In spite of the fact that Panama has been a highway of international commerce for more than four hundred years, considerable areas are still known only vaguely. The continental divide is crossed by only two highways and one railway, all of them within or adjacent to the Canal Zone, and it is crossed by few trails. Even in the lowlands, large tracts of most fertile soils remain uncultivated.

The topography has been accurately mapped only in the vicinity of the canal, such portions of the coast or other areas as the United States War Department has considered of strategic importance, and in the immediate vicinity of the Pan-American or Inter-American Highway. Other mapping has been done by oil, mining, and fruit companies, and it is of a limited and sketchy character. The country has been photographed from the air for the purpose of constructing an accurate topographic map, but this project will not come to fruition for some years.

About 1,700 square miles in the Intendencia of San Blas, and adjacent areas of the provinces of Darien and Panama are under the control of the Cuna Indians, and are not open to exploration except with their consent, which is almost never given. The topography of this region is known mainly from air observation, although two crossings of the Intendencia of San Blas have been made under military protection, one in 1870 by Selfridge and another in 1947 by Thompson.

### GEOMORPHOLOGY

The general form of the country is an irregular sigmoid, elongated in an east-west direction. Its outlines are broken by one large and several small peninsulas; the large one—the Azuero Peninsula—forming the west shore of the Gulf of Panama. This, with two smaller ones, the Burica Peninsula and the Soná Peninsula, are on the Pacific coast; two still smaller ones, the Valiente and San Blas peninsulas, are on the Caribbean coast. If the ocean were withdrawn to the 100-fathom isobath, the area of Panama would be increased by about one-third, most of the addition being on the Pacific side. The elongated sigmoidal form would still be preserved, but the large Azuero Peninsula would no longer be recognizable.

The eastern end of the country is in a more advanced stage of the erosion cycle than the western, and this difference extends across the national boundaries, with the flat basin of the Tuira River of Darien Province merging with the swampy plains of the Atrato in Colombia; while in the west, the rugged continental divide between Bocas del Toro and Chiriquí rises to the lofty volcanic peaks of Costa Rica

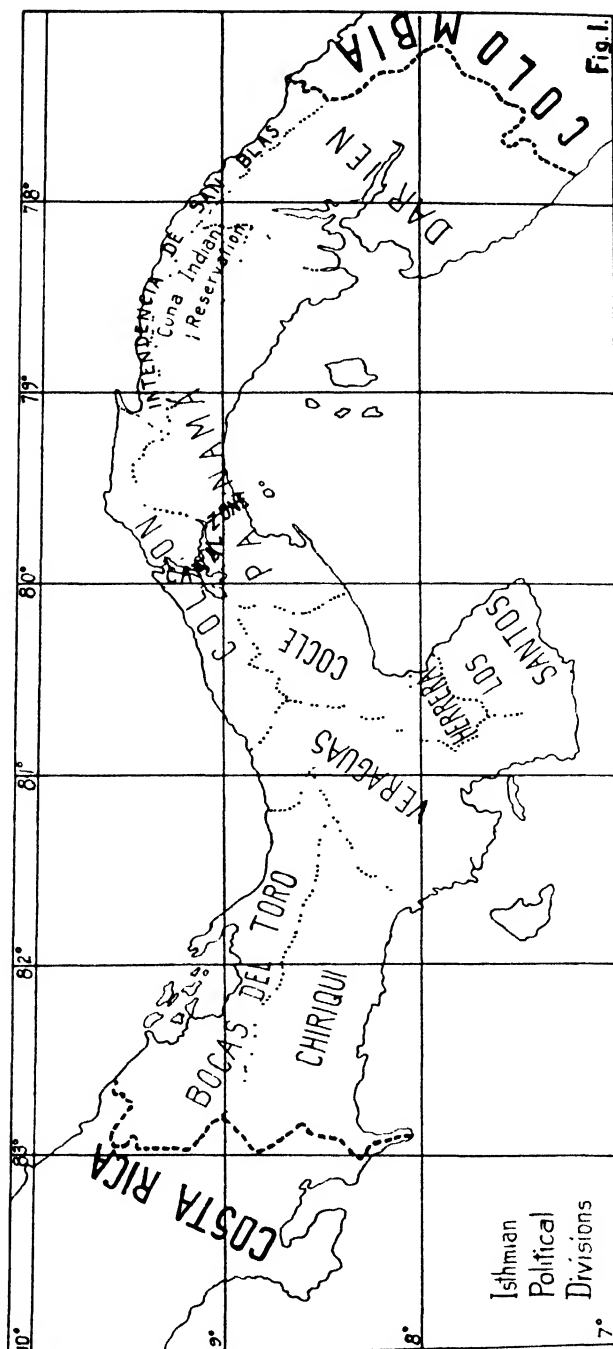


Figure 1 Isthmian political divisions

(fig. 2). The coastal plain and adjacent lowlands are wider on the Pacific than on the Caribbean side, and this difference extends out to the edge of the continental shelf. If the map were continued to the northwest, the relations between the coastal plain and the continental shelf on the two coasts would be seen to reverse itself, the plain on the Caribbean side becoming wider, that on the Pacific narrower. This physiographic change is evidently the surface expression of a change in the underlying rock structure.

### WESTERN PANAMA

The lowlands of the Pacific side of western Panama can be divided into five distinct physiographic provinces:

1. The *Burica Peninsula*, on the international boundary at the southwestern corner of Panama and the southeastern corner of Costa Rica, is a tightly folded and faulted area, the exposures showing rocks of the basement complex and the entire known sedimentary section of Panama, with the possible exception of the Oligocene, which has not been identified, as yet. Marine Pleistocene occurs at elevations of 100 feet or more. The maximum relief is over 2,500 feet, with the highest point within a mile of the west shore, and the divide between the east-flowing and west-flowing drainages lies close to the west coast from this point to the tip of the peninsula. The short high-gradient streams flowing west are rapidly beheading the long low-gradient streams flowing east. The rocks of the basement complex are mostly in the northwest corner, and the sedimentaries curve round them in arcuate forms, convex to the northeast. Differential resistance to erosion has resulted in a rugged topography, but the surface of the high ridge of basement rocks is so smooth as to suggest peneplanation prior to the last elevation. An extension of this surface tilted to the northeast at about 3 degrees would meet the successive crests of the ridges of sediments, indicating that the entire peninsula was once peneplaned and then tilted to the northeast in late Pliocene or Pleistocene time. In Recent time the peninsula was an island, and it is now a tombolo tied to the mainland by delta deposits. There is almost no continental shelf on the east side, but there is one on the west side, two to three miles wide.

2. The *flat lands at the head of the Burica Peninsula*, composed of Recent alluvium, occupied by the banana farms of the Chiriquí Land Company are a composite delta formed by rivers from the mainland and from the peninsula. Until recently a residual lake remained near the center of the area. This flatland extends from Golfo Dulce on the west to Rio Chiriquí Viejo on the east. Water wells of the

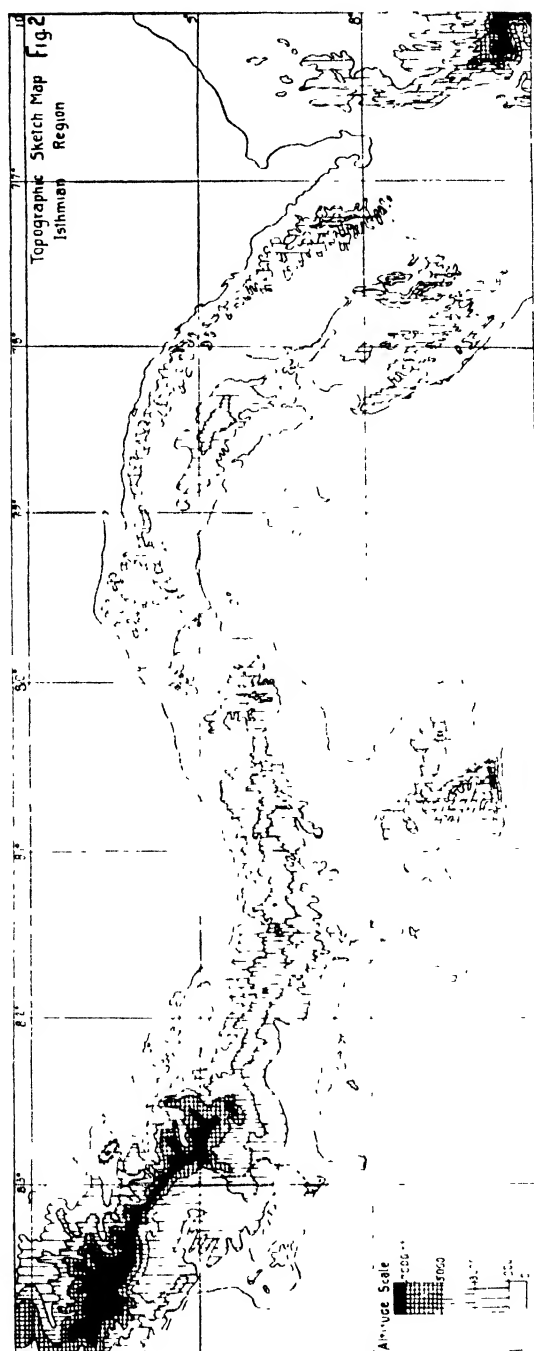


Figure 2 Topographic sketch map - Isthmian region

Chiriquí Land Company have penetrated more than 200 feet of alluvium. An ancient river system, now submerged, crosses the continental shelf. (Terry, 1941.)

3. A *volcanic outwash plain* extends from the Rio Chiriquí Viejo on the west to the vicinity of David on the east. The maximum relief is 900 feet. Volcanic ejecta cover folded Tertiary sediments. The region is a smooth plain for the most part, but hills of Tertiary sediments appear near its northern edge. Near Concepcion about 14 miles from the coast, a fault-line escarpment separates it from the higher area to the north, in which the streams run in deep box canyons, while below the scarp the channels are shallow, and the streams run out of control in the rainy season. The coastal margin is swampy. The continental shelf widens from 10 miles at the west to 20 miles at the east.

4. *David to Tolé*. This is a maturely dissected belt of tilted and folded Tertiary sediments, with numerous plugs, dikes, sills, and flows of andesite. The igneous outcrops and the numerous faults interfere with the normal development of the erosion pattern. Most of the streams are consequents. The maximum relief is about 1,000 feet, but the average is less than half that. The high points are mostly volcanic plugs, dikes, or lava-capped mesas like the Gran Galera de Chorchá. The coast line is serrated with numerous small islands, and the lower stream courses have been drowned by recent invasion of the sea. The continental shelf widens from 20 miles at the west to 50 miles at the east.

5. *Peninsula of Soná*. This is a rugged igneous area, the rocks being mostly or entirely basement complex. The maximum relief is about 1,500 feet. There is a ria coast and the continental shelf is about 50 miles wide.

On the opposite, or Caribbean coast, some four coastal provinces may be distinguished:

1. *Puerto Limon to Old Harbor* (Costa Rica). This is a flat swampy coastal plain, two to five miles in width, with an extension up the valley of the Estrella River ending in a bolson valley floored with gravel and boulders, with a thin cover of alluvium. Smaller valley flats extend up the Banana and Bananito rivers. The alluvial cover of the coastal plain is thin over folded Tertiary sediments, which are occasionally exposed in stream beds. Drowning of stream valleys is less marked than on the opposite coast of Chiriquí. The continental shelf is seven to eight miles wide from Puerto Limon to Cahuita Point, whence it narrows rapidly to about two miles at Old Harbor. The straight line of the coast suggests fault control, and the rapid

narrowing of the continental shelf east of Cahuita Point, with its steep outer edge carries a similar suggestion.

2. *Old Harbor to Monkey Point* (Costa Rica). This region has no coastal plain. It is composed of sandstone and conglomerate hills of middle and late Miocene age with some Pliocene. These form a belt of hills along the coast, back of which is the flat meander belt of the Sixaola River, about five miles wide. The continental shelf is about two miles wide.

3. *Monkey Point to Chiriquí Lagoon* (Panama). This area consists of a swampy coastal plain, seven to eight miles wide, over which the Sixaola and Changuinola rivers meander. The wide flood plain of the Sixaola extends inland to the bolson Talamanca valley, filled with heavy gravels and boulders with a thin cover of alluvium. The continental shelf is seven to eight miles wide and at the mouth of the Sixaola is deeply notched, apparently because of faulting. (Terry, 1941.)

4. *Almirante to the base of the Valiente Peninsula*. This region consists mainly of the shallow, flat-bottomed Chiriquí Lagoon, which has a maximum depth of about 20 fathoms. In the lagoon are numerous islands of Miocene sandstones and shales, with interbedded and intruded lavas. Along the inner margin of the lagoon from Almirante to Chiriquí Grande, similar hills of sediments and andesite form the coast, but from Chiriquí Grande to the base of the Valiente Peninsula is a swampy, alluvial coastal plain, five to six miles wide. The Valiente Peninsula is a tombolo of Miocene sediments and igneous rocks. The continental shelf varies from about 5 miles wide at Valiente Point to 20 miles at the offshore island, Escudo de Veraguas, from which it narrows rapidly to 10 miles at the base of the peninsula.

Between the two coastal regions just described, the cordillera of the continental divide rises from about 3,000 feet at the head of the Rio Tabasará at the eastern edge of the region to 12,861 feet at Chiripó Grande, southwest of Puerto Limón. The axial portion of the cordillera may be conveniently divided into three parts.

1. *Eastern part, the Serranía de Tabasará*. The crest of the cordillera rises from 3,000 feet at the head of the Tabasará, to 9,265 feet at Cerro Santiago, a Pleistocene (?) volcano, from which it descends to about 4,000 feet near the 82nd meridian. There is a fairly even slope on each side to the two coastal plains, with consequent streams running straight down the slope.

2. *Central part from 82° to 82° 30' W.* The crest line has an average height of 5,000 to 6,000 feet with three peaks—Hornito

(7,200), Cumbre de la Playa (8,235), and Horqueta (7,440 feet). These are apparently all volcanic, probably of late Pliocene or Pleistocene age, but they have not been investigated. The writer crossed the divide on a trail between Hornito and Cumbre de la Playa, and noted the flatness of the divide for a width of a mile, more or less; and he was informed that the Rio Chiriquí rises in a shallow lagoon in a similarly flat area on the crest of the divide. It is not known whether the flattening is erosional or due to flat-lying lava beds, but the last rocks exposed on the south side before reaching the crest, are crystalline, followed by andesite at the crest, but no flow structure was seen.

3. *Western part—the Cordillera de Talamanca.* This portion of the cordillera has eight peaks above 10,000 feet on the divide itself, and four others at short distances from the crest-line. The writer has not crossed this part of the divide, but has climbed one of the peaks on the south side, El Barú, a Pleistocene volcano. Reports of its activity in historic time are of questionable authenticity.

El Barú, which dominates the landscape from almost any point in the province of Chiriquí, is for that reason usually known as the Volcan de Chiriquí. Its peak, 11,410 feet above sea-level, is the highest point in the Republic of Panama, and is about eight miles south of the continental divide. The present cone, which is far from perfect, has an ellipsoidal base about nine miles long on the main axis, which extends on a nearly east-west line, and about seven miles on the shorter axis. This cone is composed mainly of heavy flows of andesite and subordinate amounts of clastic material. Examination of slides made from these Pleistocene flows does not disclose any perceptible difference from slides cut from flows of Miocene age or those of the basement complex.

There are several craters, the largest of which lies west of the high peak and debouches through an opening half a mile or more wide upon the Llanos del Volcan, a gently sloping plain, from which rise a few small andesite hills, which may be volcanic plugs, or remnants of older flows. There are several undrained depressions, two of which are occupied by perennial ponds. The material underlying the surface, so far as can be seen in the erosion channels, is mainly elastic and most of it appears to have been water deposited.

From the Llanos del Volcan a continuous gentle slope extends southward some eighteen miles to Concepcion, where it is intersected by an eroded fault scarp. This sloping plain is drained by radial streams, running in deep box canyons. The interfluvial areas are wide and not much dissected on the upper part of the slope; the lower areas are more cut up, but the entire region has an appearance of

extreme topographic youth. The material is mostly elastic and was distributed by explosion and by water. The breach in the old crater wall suggests that a crater lake was released by faulting or by eruption, the succeeding floods spreading loose materials which were carried farther by slope wash. It is possible that other vents contributed, but by far the greater part was apparently derived from El Barú. The area covered by the volcanics has maximum dimensions of about 25 miles east-west and about 30 miles north-south. Near the peak on the east are three small craters of later date with steep andesite walls and flat floors, largely pumice. Narrow notches in their walls cut by the overflow lead to the Cochea River. There are no signs of recent activity in the small craters, but there is a tepid sulphur spring in the large one.

The base of the lava flow cone is overlapped by the elastics, and the platform on which it rests is not visible, but is presumed to consist of sediments of Mid-Miocene age which emerge from beneath the elastics at both the east and west margins of the volcanic area at altitudes of 3,000 to 4,000 feet.

The writer has crossed the continental divide a few miles west of Cerro Santiago at the head of the east fork of Cricamola River, and on the south side of the divide crossed a steep slope of volcanic ash which looked as fresh as the material in the crater of Irazú, an active Costa Rican volcano. The ash was so loose that the accompanying Indians insisted on spreading out to a spacing of 30 feet between men, to avoid starting a slide. It was the writer's impression that Cerro Santiago has been more recently active than El Barú. Most of the high peaks in this part of the Cordillera are probably volcanic and of Pliocene or Pleistocene age, but the divide has not been examined except here and at the crossing between Rio Chiriquí and Rio Guarumo.

The Cordillera de Talamanca continues northwestward in Costa Rica, trending slightly more to the west, and increasing in altitude, to Chirripó Grande at 12,861 feet, from which it descends slowly to the Meseta Central of Costa Rica. According to Lohman (1934), the latter portion is composed of Tertiary sediments dipping north under the cover of Pleistocene and Recent volcanics in the Meseta Central. He shows these sediments as resting on a basement of crystalline deep-seated rocks, which are here and there covered by Pliocene, Pleistocene, or later volcanics; and he considers the crystallines to be older than the basic lavas which cover them. Gabb (1875) considers the granite of Pico Blanco, near the continental divide just west of the international boundary to be a later intrusion which has metamorphosed the Mid-Miocene sediments. The writer thinks Gabb



was mistaken, as the Gatun conglomerate contains pebbles and cobbles of granite. In general, the topography of the cordillera is distinctly youthful; but there is an area on the Pacific side of the divide near the international boundary which shows considerable stretches of smooth surface beveling the steeply tilted Oligocene and Miocene strata. These sloping plains at the 3,000- to 4,000-foot level are very clearly seen from the air in the region from Breñon to Canas Gordas. They slope gently to the southwest and the beveling of the surface is believed to be of contemporaneous origin with that of the now-dissected peneplane beveling the ridges of the Burica Peninsula. Both peneplanes dip inward toward the intervening flats of the compound delta which ties Burica Peninsula to the mainland. This delta is still close to sea level. The inward tilting of the peneplaned areas is believed to be due to underthrusting from the Pacific side, and to intrusion from below under the cordillera.

#### CENTRAL PANAMA

On the south shore of the Azuero Peninsula, an andesite cliff fronts the sea for most of the distance from Punta Naranjos to Punta Búcaru. The narrow width and steep outer edge of the continental shelf suggest close offshore faulting. Near Rio Ocones, west of Morro Puerco, shales and slates apparently underlying the andesite, dip steeply toward the sea. No fossils were found. It is possible that these rocks are of Cretaceous age, but in any case the andesite belongs to the basement.

From Morro Puerco, a narrow coastal plain widens gradually to Punta Búcaru, where it meets the floodplain of Rio Tonosí. This flat extends inland for six or seven miles. From Punta Búcaru eastward to Cape Mala the continental shelf averages about 10 miles in width, but the coastal plain narrows eastward from the mouth of Rio Tonosí to the limestone-andesite contact, about eight miles distance, where the andesite cliffs reappear and form the coast line to Capa Mala, and north along the shore of the Gulf of Panama nearly to Mensabé, where a narrow coastal plain begins and widens slightly northward to the deep reentrant occupied by the delta of Rio Santa Maria. Here the coastal plain merges with the Santiago plain which separates the highlands of the Azuero Peninsula from the foothills of the continental divide. This is a flat erosional surface cut on Oligocene and Miocene sediments, for some forty miles westward to the head of Montijo Bay. These flats extend south along the coast of the bay about 25 miles to the igneous-sedimentary contact north of Rio Toro. The Oligocene and Miocene are intruded and interbedded with basic lavas and tuffs





over the entire area, a condition which continues north to within a few miles of the continental divide and east to the vicinity of Anton. Numerous vents through which these volcanics issued can be seen in the form of dikes and volcanic craters, one of which is described by Joukowsky and Clerc (1906): "From the port of Aguadulce to Chitré passing through Sta. Maria, Parri, Parita, and l'Harena describing an arc more or less parallel to the shore with a total length of more than a hundred kilometers I saw nothing but eruptive rocks, lava, or ash. South of Sta. Maria is found a circular plain completely surrounded by a chain of low hills. At its highest point is an outcrop of basic rock with augite microlites. The general arrangement of the rocks suggests a volcanic vent. There are also volcanic rocks, lavas, and cinders which are found from the village of Chitré to the port, forming a plain a little above sea level. On the road from Chitré to Macaraacas for a dozen kilometers, one sees nothing but volcanics. At this distance (roughly calculated) is the first sedimentary outcrop, a calcareous marl striking NNE." (Author's translation.)

Other similar and larger volcanic vents can be seen west and north-west of Aguadulce.

The lavas along the coast near Chitré mentioned by Joukowsky apparently overlie the sedimentaries of late Oligocene and early Miocene age, and may be younger than early Miocene. The sediments dip beneath them near Las Tablas and at other points. The peneplane which cuts across them can hardly be older than middle Miocene since it bevels early Miocene strata. The coastal plain continues east beyond Anton to Chame, and from the coast the smooth gentle slope continues 50 miles beneath the sea to the edge of the continental shelf.

The Azuero Peninsula, aside from the coastal plain, consists of two upland areas, separated in the middle by the Tonosí basin and its narrow connection with the Santiago plain by way of Juanbaeho and Macaraacas. The highland area west of the Tonosí basin is a deeply dissected plateau, which like the Burica Peninsula, fronts the Pacific with a steep andesite cliff, the highest point of which is less than three miles from the coast, with the drainage running northwest to the Gulf of Montijo. The east side of the plateau is separated from the Tonosí basin by a steep scarp, striking about N. 23° W. The western half of the Azuero Peninsula has thus the appearance of a fault block, elevated on its eastern and southern sides and tilted to the northwest. The plateau area east of the Tonosí basin is somewhat smaller and rises to lesser heights, with no obvious suggestion of tilting. The rocks of higher parts belong mostly to the basement complex, but some of the volcanics are younger. MacDonald (1937) considered Cerro

Quema to be a Pleistocene volcano. The drainage is radial from the central area of the eastern plateau.

On the opposite Caribbean coast, the continental shelf varies from 3 to 12 miles in width, and there is no coastal plain from Rio Pasaula eastward to Belen. Over this distance, the andesite foothills of the cordillera come down to the sea, and are cut up by sharp V-shaped valleys striking N. 45° W. at an acute angle to the coast, instead of running directly down the slope from the continental divide, as might be expected of consequent streams running over unstratified rocks. The parallel stream courses and unexpected orientation suggest control by faulting.

From Belen east to Coelé del Norte the surface as seen from the air, is a series of low parallel ridges striking east-west and rising slowly to the continental divide, which for a distance of twenty miles east of La Pintada averages about 2,000 feet in height. The ridged surface resembles the Santiago plain, and like it seems to be composed of interbedded elastics and volcanics, the latter forming all, or nearly all, the formation on the west, with the elastics increasing to the east. Near Coelé del Norte, specimens seen by the writer were dark gray to black foraminiferal shale resembling the Uscari of early Miocene or late Oligocene age, which had been intruded by an andesite dike and slightly mineralized along the contact. However, on a canoe trip up the river, all exposures seen were igneous. The ridged surface of the flows and elastics, looks like a peneplane which has been slightly elevated, tilted toward the north, and somewhat eroded. This conclusion is supported by the fact that east of Belen the stream courses are in general normal to the coast, as might be expected on a tilted peneplane sloping to the sea. It is the writer's conclusion that this surface is actually of equal age with the south coast peneplane, but has suffered greater elevation and tilting in post-Miocene time. The corrugated surface is the result of erosion of the weaker beds, following the tilting.

This corrugated surface becomes flatter and wider as one approaches the canal, bending south to include Gatun Lake, but east of the lake is cut off sharply by the contact with the basement rocks. This contact strikes about N. 30° E., reaching the sea about halfway between Colon and Portobello. On the Pacific coast, igneous plugs and dikes rise above a surface which appears to be mainly andesite flows west of Anton, and rhyolite flows and tuffs to the east, with some interbedded elastics, partly marine and partly terrestrial. Like the area described above, the surface in general appears to be an elevated, tilted, and slightly eroded peneplane east of the Bay of Chame.

Between these two tilted peneplanes is a mountain group, flanked by two volcanic cones, El Valle on the south, San Miguel de la Borda on the north, between which the continental divide traverses an area of rhyolites and granites which culminates at the east in La Campana, 3,300 feet in height. The volcanics of El Valle are rhyolite ash and rhyolite flows. Those of San Miguel de la Borda have not been investigated.

The well-preserved slopes of the El Valle cone with their youthful drainage channels, led the writer to ascribe to it [in Schuchert's (1935) volume] a Pleistocene age. Jones (1950) objects to this and apparently considers it Miocene, saying that the slopes have not been eroded because of the porosity of the tuffs. It is difficult to reconcile this view with the fact that several volcanoes of Miocene age in the area between Santiago, Aguadulce, and Las Tablas have been completely eroded and the surface peneplaned as described by Joukowsky and Clerc (1906). Some of these Miocene volcanoes were of a size comparable to El Valle. It is a fact, however, that the materials ejected by the El Valle volcano are considerably older than the cone itself, and may be of Miocene age. The El Valle volcano is of the caldera type. Its crater was localized by the intersection of four faults, two striking N. 10° W. and two striking N. 60° E. The two latter parallel the continental divide, which is probably itself a fault line scarp. The north and west walls of the El Valle crater are rhyolite, the south wall and at least a part of the east wall rhyolite tuffs and ash, very well stratified. They strongly resemble the Panama tuffs at Diablo Heights in the Canal Zone, and may well be of the same age (early Miocene). The eruptions which formed the cone, however, took place at a much later date, and the Miocene ash was ejected after the manner of the Krakatoa eruption, with a minimum amount of new material. On the floor of the crater, about three miles northwest of the village of El Valle, a well was drilled to secure a domestic water supply for the home of Don Enrique Coronado. This well penetrated 65 feet of tough blue clay, capped by three feet of loose sand, neither of these deposits resembling the stratified ash of the crater walls. The well was unsuccessful. The clay is apparently a lake deposit, made in a water body which filled the crater. The lake was finally drained by the head of Rio Anton cutting along the shattered rhyolite on one of the N. 60° E. faults along which movement has taken place in Recent time.

On the north side of the divide, the San Miguel de la Borda cone has not been investigated by the writer, but as seen from the air, appears to be a volcanic ash cone, somewhat smaller than El Valle.

Central Panama, east of the canal, has a well-developed coastal plain on the Pacific side, which widens from two miles at the eastern limit of Panama City to 15 miles at the Bayano River. The flat surface continues beneath the sea to the edge of the continental shelf, about 75 miles distant at the widest part. On the surface of this plain appear a few monadnocks of igneous and sedimentary rock, those offshore forming the Pearl Islands and other smaller islands of the Gulf of Panama, while the inland monadnocks of the coastal plain are on a smaller scale, but of the same general character. This plain, like the Santiago plain and that of eastern Chiriquí is cut across the edges of tilted marine sediments of Oligocene and Miocene age, which are interbedded with, and intruded by basic volcanics, less numerous than those of Chiriquí. The continental shelf is ended at the south by an arcuate escarpment, convex to the north, with a maximum height of 10,000 feet, and a maximum slope of about 20°. It is almost certainly due to faulting. A conspicuous narrow slot bisects the continental shelf in a north-south direction just west of the Pearl Islands, and during the Pleistocene withdrawal of the sea, was occupied by the channel of the Bayano River. No such submarine channel connects the mouth of the Tuira River of Darien with the edge of the continental shelf, although the Tuira discharges a much greater volume of water than the Bayano. It is therefore believed that the slot west of the Pearl Islands is not due to Pleistocene stream erosion but to faulting. A similar rift about 20 miles long cuts the smooth surface of the continental shelf southeast of the Pearl Islands (plate III). It has a maximum depth of 300 to 350 feet, and a maximum width of two miles. It parallels the coast and is also evidently due to faulting. It is closed at both ends.

An interesting feature of the continental shelf on the two sides of the isthmus is that on the Caribbean side, the shoulder which marks the top of the outer escarpment is around the 42-fathom isobath, while on the Pacific side it is around the 72-fathom isobath, except along the eastern side of the Burica Peninsula and the western half of the Azuero Peninsula. Since this shoulder is no doubt related genetically to the Pleistocene withdrawal of the sea, it would appear that the present difference in elevation indicates differential movement in post-Pleistocene time on a regional scale, with sinking on the Pacific side.

The continental shelf on the north coast of central Panama, east of the Canal Zone, averages about 10 miles in width and its outer edge parallels the coast in a gentle arc, convex to the north. There is no continuous coastal plain, but rather a series of small terraces

notched across the igneous rocks of the basement. They are seldom more than a mile or two in width, and are interrupted by fingers of the interior plateau extending to the sea.

The interior plateau is dominated by an arcuate ridge, convex to the north which marks the northern edge of the basin of the Chagres. The crest of the ridge varies from 1,500 to 2,000 feet in height with occasional peaks, the highest of which, Cerro Bruja, reaches 3,200 feet. The ridge is breached by a fault rift which is occupied to the south by the Boqueron River running to the Chagres. This rift is occupied by sedimentary rocks of unknown age, but the ridge itself is, so far as known, entirely igneous, and belongs to the basement complex. The rift mentioned above strikes about N. 20° E. A much larger rift, or graben, forms the basin of Chagres River; the lowest part of the downthrow block is now occupied by Madden Lake. The basin of the Chagres lies between two major faults striking N. 70 E., and is cut by another system striking N. 20° E. to N. 30° E. These two fault systems control the drainage pattern of the Chagres and extend to the Caribbean coast, where the eastern end of the Chagres rift is occupied by the Gulf of San Blas. The part intervening between the Gulf of San Blas and the Madden Basin has been little explored, but is supposed to consist entirely of the igneous rocks of the basement complex. The topography is exceedingly rough, cut by V-shaped stream valleys, and may be classified topographically as a mountain region in early maturity. Looked at from the air, it appears to be topped by the remnants of a peneplane at about 2,500 feet, with a few rounded monadnocks rising to 3,000 feet. The size of the remaining flat remnants of the peneplane is not known, but they cannot be large.

The writer crossed the divide on a traverse from Chepo to the head of the Gulf of San Blas (plate III) and observed the flatness of the crest between the head of the south-flowing Mamoni and that of the north-flowing Sangondí, tributary of the Mandinga. The flat area was narrow, and apparently not due to flat-lying lavas.

#### EASTERN PANAMA

In eastern Panama, the ridge of basement rocks forming the south escarpment of the Chagres-San Blas graben continues, constituting the continental divide, which extends from the head of the Gulf of San Blas to the Colombian border at Cerro Gandí, and continues to and beyond Cerro Tacarcuna. It lies 5 to 10 miles from the Caribbean coast, and is an arcuate igneous ridge convex to the northeast, for the most part less than 2,000 feet high, with some notches less than



1,000. It is bordered on the south and southwest by a parallel arcuate lowland, a continuation of the Pacific coastal plain of central Panama. Most of this plain is below the 300-foot contour. The northwestern end of this arcuate lowland is occupied by the basin of the Bayano River, the southeastern end by the Tuira-Chucunaque basin. The two basins are separated by a divide so low as to be almost imperceptible from the air. Indians of the upper Chucunaque have told the writer that piraguas (Indian dugouts) are sometimes dragged across the divide from one drainage system to the other. In both basins the level surface of the lowland is cut across tilted sediments of Oligocene and Miocene age. The youngest of these, the Chucunaque formation, is of late Miocene and perhaps Pliocene age. The erosional beveling must have been accomplished mostly in Pleistocene time. At the Bayano-Chucunaque divide the lowland is 10 to 12 miles wide, but from the divide it widens rapidly to the south, and in central Darien Province reaches a width of 30 miles, which with the exception of a few monadnock ridges has been not only peneplaned, but largely base-leveled, so that hundreds of square miles are practically at the level of high tide. This base-leveled swampy region extends from the Chucunaque at the mouth of the Sueubí to Real on the Tuira, and is bounded on the west by the Rio Sabana and Lower Rio Tuira from the mouth of the Lara to Chepigana on the Tuira and thence south to Tucutí on the Rio Balsa, enclosing an area of about 600 square miles. This area is uninhabited except at its outer edges, and was apparently uninhabited when Balboa made his crossing along its northern end in 1513. Semiaquatic mammals such as the tapir, capybara, and paca can remain there over the rainy season, but other large mammals enter these swampy flats only during the dry season, when it becomes for the Indians, a valuable hunting ground. The larger oxbow lakes hold stagnant water, covered with green scum, throughout the dry season, and outside the meander belts of the larger rivers, water-bearing vines are the only safe source of drinking water for the hunter in February, March, and April.

The largest of the monadnocks in this base-leveled area is the Sanson ridge, the core of an anticline, which rises to a height of 1,800 feet at one point, according to the Air Chart.

The fact that this base-leveled surface still stands at tide level, indicates isostatic stability from its completion to the present, and this is borne out by the seismic records. Few shocks have been recorded from Darien Province.

The eastern side of the arcuate lowland belt continues southward to the head of the Tuira, where only a low ridge separates it from

the broad flats of the Atrato, which are obviously its continuation, but cut off from it by faulting of fairly recent date. Hildebrand (1938) has noted that the fresh-water fishes of the Tuira (Pacific drainage) resemble those of the Atrato (Atlantic drainage) more closely than those of the Chagres resemble those of the opposing Pacific slope.

The Pirri Range of central Darien Province, an asymmetric anti-clinal fault block, separates the upper Tuira valley from the valley of the Balsa to the west; the Balsa, in turn, is separated from the Sambú by another fault block of basement rocks, and another fault block of mainly basement rocks separates the Sambú from the Pacific. The Pirri block and the block between the Balsa and the Sambú approach each other closely at the Colombian border, where the summits of each are beveled by a series of small level areas, so flat that water stands in undrained depressions through a large part of the year. The surface of these flats is around 4,000 feet on the Pirri ridge and slightly less on the Altos de Aspavé across the Balsa valley. These flats appear to be peneplane remnants, and if so, the peneplane must have been cut following the mid-Tertiary folding which preceded the deposition of the Gatun (middle Miocene), since it is hardly conceivable that an older peneplaned surface could have remained level following intense asymmetric folding in the Tertiary. The interval between the 4,000-foot mid-Miocene peneplane and the sea-level Pleistocene peneplane of central Darien therefore marks for this area the amount of uplift from mid-Miocene to Recent times. The upper peneplane surface of the Pirri Range slopes gently northward and more rapidly southward from a high point on the Colombian frontier at the head of the Rio Salaguí ( $7^{\circ} 44' \text{ N.}, 77^{\circ} 44' \text{ W.}$ ) The elevation of the high point, which is the summit of a monadnock on the old peneplane, is 5,134 feet on the Aeronautic Chart. Other high points in southeastern Darien are Cerro Pirri on the Pirri ridge at 4,973 feet, and Cerro Sapo on the ridge west of the Sambu at 4,264 feet. The highest point in Darien is at the summit of Cerro Tacarcuna on the continental divide at 6,180 feet.

One of the least-known areas of eastern Panama is the mountain block which divides the upper Bayano valley from the Pacific coast. As the area from the crest of this divide to the Caribbean coast is entirely Indian reservation, from which outsiders are excluded, and since the coastal belt on the Pacific has been unattractive to oil geologists, there has been no mapping of the intervening ridge.

Topographically it is an irregular mountain block rising to a high point of 5,330 feet, elongated in a N.  $30^{\circ}$  W. direction and

apparently a structural continuation of the igneous divide between the Sambú and the Balsa. The mountain ridge sinks to the north-west and west and ends about five miles east of the mouth of the Bayano. Like all the other physiographic provinces of eastern Panama, it is gently arcuate, with convexity to the northeast. Its rocks wherever examined at its boundary are andesites, probably of the basement complex, but on the upper Rio Congo, the writer saw boulders of mica schist in the stream channel.

Between the ridge and the coast is a coastal plain, varying from 3 to 10 miles in width with an irregular inner boundary. The underlying rocks of the plain, so far as identified, are Oligocene and Miocene shales. Much of this coastal plain is mangrove swamp. The gentle slope of its surface continues southwest beneath the ocean to the Pearl Islands, and on to the edge of the continental shelf, 50 miles away.

San Miguel Bay and its eastward continuations, the estuaries of the Tuira and Sabana rivers, as well as its northward fingers, the estuaries of the Congo and the Cueunatí, are the result of flooding due to the rise of sea level, following the melting of the Pleistocene icecap. The shores of these estuaries mark the limits of the meander belts of the respective rivers during Pleistocene time. In the case of the Tuira, which carries all freight for the Tuira-Chucunaque basin, the meanders of the old channel at the bottom of the estuary are well known to the sailors of the launches running between Panama City and Darien, and their curves are followed closely at low tide. A stranger, watching with amazement the winding course followed by the helmsman of such a craft on the wide estuary, would, if he mapped the course, have a close approximation to the meanders of the Tuira channel in Pleistocene time.

The geomorphology of Panama may be summed up briefly as follows:

*Eastern Panama*—late stage of the erosion cycle, wide flats, meandering rivers bordered by oxbow lakes in the Chucunaque-Tuira basin, drowned lower valleys. Mountains in mature state, with high peneplane remnants near south border—major physiographic features arcuate, with fault control on N. 30° W. and N. 25° E. lines. Block faulting of mountains following folding. Evidence of recent isostatic stability.

*Central Panama*—slightly earlier stage of erosion cycle. Streams mostly consequents with fairly straight courses. No drowned valleys on north coast and on Pacific coast small, mostly limited to ends of

the Santiago plain. Arcuate form of physiographic features less apparent than in eastern Panama. Block faulting shown in some areas. Volcanic cones, Cerro Quema, El Valle, and San Miguel de la Borda appear young. Coastal plain wide on Pacific side, narrow on Caribbean. Continental shelf the same. Faulting of graben or rift type east of Canal zone, faulting along coast of Azuero Peninsula and continuing to the west.

*Western Panama*—early stage of erosion cycle. Narrow coastal plain and wide mountain area in youthful stage. Streams mostly consequents, but some meandering on coastal plain. Deformation of Pleistocene peneplane in southwest indicates post-Pleistocene tectonic activity. Pleistocene volcanoes, El Barú, and Santiago, and active volcanoes to the west in Costa Rica, and seismic activity in western part indicate lack of isostatic adjustment. Youthful mountain morphology partly due to Pleistocene and Recent vulcanism.

## IGNEOUS ROCKS

About one-half the surface of Panama is made up of igneous rocks, most of which are of basic extrusive types. Crystallines are for the most part confined to the region of the continental divide or to other high mountain areas, where they appear as the result of the erosion of a cover of andesite or basalt flows, a fact noted by Hershey (1901) in central Panama, and by Lohman (1934) in Costa Rica. Gabb (1875) considered the granite of Pico Blanco near the Costa Rica-Panama boundary to be a post-mid-Miocene intrusion, but Lohman (1934) disagrees. Wagner (1862) saw granite on the north side of the divide near the head of the Gulf of San Blas. MacDonald (1919) says the Chagres brings down granite float. The writer saw granite on the head of Rio Indio north of El Valle, and has been informed that it occurs in the Campana district, 20 to 25 miles west of the Canal Zone. Hershey (1901), Taylor (1852), and Wagner (1861) mention granite in the region adjacent to the north coast near the Coole-Veraguas border. Riddell (1927) says granite occurs on the south slope of the continental divide, about 20 miles north of La Mesa in Veraguas. In the Azuero Peninsula, granite float was seen by Dunn (personal communication) on the head of Rio Quebro, west of the Tonosí basin; and the writer collected a granite specimen from an outcrop about 10 miles southwest of Las Tablas on the trail to Tonosí. The specimen was given to MacDonald (1937), who studied a thin section and reported: "A light-colored, fine-grained, sodic granite, which weathers pinkish. . . . The orthoclase and albite, present in both large and small crystals, have been considerably

altered to epidote, calcite, and sericite. Some micrographic intergrowths of quartz and orthoclase were noted. Magnetite appears as a primary mineral, and is also secondary, associated with chlorite from the alteration of hornblende. The alteration of this granite may be due to later igneous intrusions."

MacDonald's conclusion that the granite was older than the adjacent basic rocks is of interest.

Light-colored quartz-bearing rock which may be granite or granodiorite has been seen near the head of the Rio Caldera in Chiriquí Province by the writer. Syenite was reported by Wagner (1861), and Hershey (1901) from the vicinity of Mineral, a few miles from the coast of Veraguas on Rio Concepcion; and Gabb (1875) remarks: "True granite rarely occurs, while Syenites are much more common."

Acidic extrusive rocks in the form of rhyolite or rhyolitic tuffs and ash, cover a large area in central Panama, south of the continental divide, mostly in the provinces of Colé and Panama between Chame and Anton. In the Canal Zone, Ancon hill was termed rhyolite by MacDonald (1919), and the Panama tuffs are mainly rhyolitic. Riddell (1927) says that Cobriza Peak in central Veraguas is rhyolite and that a rhyolitic cap formerly covered Remance hill.

Serpentine was seen by Dunn on the west side of the Azuero Peninsula on the upper Rio Quebro, and he says that it was also reported to him from Cerro Negrito on the coast of Montijo Bay.

Intrusive basic rocks are probably to be found over much of the isthmus, but have been seldom reported. A specimen collected by the writer in the Azuero Peninsula about 12 miles inland from Las Tablas was sectioned and examined by MacDonald (1937), who reported it a quartz gabbro, somewhat altered by later intrusives.

With the exception of the rhyolites of central Panama, there seems to be little difference in the character of the extrusive igneous rocks which overlie the crystallines. The dominant type is andesite; basalt is next most common. Vulcanism seems to have been more or less continuous from Eocene to Pleistocene time. There are no sediments in which ash or tuff cannot be found; in many it constitutes a large part of the rock. There appears to have been a particularly active volcanic period in mid-Miocene time in connection with the uplift and deformation which preceded and accompanied the deposition of the Gatun formation in western Panama, but this is not true in Darien. Since that time active vulcanism seems to have been limited to the area west of the canal.

In the region between the canal and Soná, tuffs, ash, and lava are included in, and interbedded with marine and terrestrial sediments

to an extent that indicates that this area was the principal site of volcanic activity in Oligocene and early Miocene times with the Pearl Islands as another center, while Chiriquí and Bocas del Toro seem to have been the principal center of late Miocene vulcanism. Eastern Costa Rica and Chiriquí were active areas in Pliocene and Pleistocene times; and western Costa Rica and Nicaragua are actively volcanic at present. There seems to have been a steady westward progression of volcanic activity since Eocene time. While late Eocene sediments carry tuff and agglomerate in all parts of the country, the highest ratio of included volcanic materials is in Darien Province, in the eastern end of the country.

The monotonously uniform character of the andesite which forms the larger part of the basement in Panama has discouraged the collection of specimens for microscopic examination. A series of slides made from specimens collected by the writer, mostly from islands in Panama Bay and the Province of Darien, were examined by Dr. A. L. Isotoff, at Stanford University in 1945. Fifty-four slides were classed as andesite, 12 as diabase, and 8 as basalt. As the writer had made some effort to collect from distinctive outcrops, the proportion of andesite is probably too low to represent truly the general character of the igneous in this area. Some typical descriptions are quoted from Isotoff:

T 3(b). Isla Saboga—Pearl Islands. West side. Andesite. Phenocrysts of labradorite and augite in a groundmass filled with microlites of andesine, grains of pigeonite and magnetite and alteration products, notably carbonate and secondary quartz.

T 12. Isla Saboga—west side—at contact with sediments. Composition similar to the preceding, but with amygdules of calcite and zeolite.

T 15. Isla Saboga—westernmost point. Andesite porphyry. This rock has a coarser-grained groundmass than the preceding, and this suggests it might be an intrusive phase.

T 21. Isla San Pablo. Andesite. A rock of trachytic texture consisting of small laths of acidie andesine and a few larger laths of labradorite. Dark minerals are absent in this section.

T 31. Isla Taboga at north end of village. Andesite (?). The rock is strongly altered—the section shows a mosaic of secondary quartz with sericite and alunite. There are vague suggestions of the original porphyritic texture.

T 36. Isla Taboguilla near Pozo Maluco. Andesite. Trachytic texture. Microlites are acidie andesine. Plagioclase phenocrysts are altered completely to a mosaic of quartz and albite. Dark minerals are represented by “ghosts” of chlorite and magnetite.

T 43. Isla Otoque—N.W. side. Enstatite Andesite. Typically andesitic texture. Microlites of andesine, grains of pigeonite and magnetite with some residual glass from groundmass with phenocrysts of plagioclase, enstatite and augite.

T 52. Chiman. (Shore of Panama Bay about 60 miles east of Canal Zone.) Hornblende andesite. Microfelsitic texture. Andesite with dominant green hornblende, partly fresh, partly changed to ghosts of magnetite and chlorite. Some augite and fairly abundant magnetite and apatite.

T 63. Rio Taimatí. (South shore of San Miguel Bay about 10 miles from coast.) Andesite porphyry. Trachytic texture. Andesine in groundmass and in phenocrysts. Much carbonate and leucoxene.

T 69. Quebrada La Jira. (Tributary of Rio Congo—Darien Province.) Biotite andesite. Microfelsitic groundmass with andesine. Green Biotite is partly chloritized. Epidote, zeolites and secondary quartz indicate an advanced stage of hydrothermal alteration.

T 75. Alhajuela Highway 1 mile S. of Cruces trail crossing. Lamprobolite andesite. Andesite with lamprobolite (basaltic hornblende) as the dominant mineral.

T 88. Setetule Mountain (Darien Province). Andesite agglomerate. Hornblende and lamprobolite andesite.

T 108. Rio Cuasi—tributary of Rio Balsa—Darien Province. Hypersthene andesite. Both ortho- and nonopyroxene are present. The former appears to be optically negative and is therefore hypersthene. Very weak pleochroism indicates low iron content.

T 116. Cerro Mongorodo. Rio Balsa area—Darien. Andesite. Microfelsitic groundmass. Plagioclase phenocrysts with inclusions of groundmass. Dark minerals resorbed and indeterminate. Much apatite and magnetite.

T 133. Volcan—Chiriquí Province. Hornblende andesite.

T 137. Boquete—Chiriquí Province. Lava flow. Lamprobolite andesite.

T 1. Isla Chitré—Pearl Islands. Diabase. A medium-grained rock with subophitic texture. The labradorite is somewhat kaolinized while the augite is altered completely to chlorite and carbonate. There is much secondary quartz.

T 17. Isla del Rey—Pearl Islands. Punta Gorda. Diabase. A coarse-grained rock consisting of labradorite and partly uralitized augite. Chlorite, zeolites and magnetite are abundant in the interstices between fairly fresh plagioclase crystals.

T 60. Isla Iguana—San Miguel Bay—Darien. Diabase. Subophitic texture. Laths of labradorite, augite, magnetite, chlorite.

T 73. Alhajuela Highway—one-half mile S. of Cruces trail crossing, Canal Zone. Diabase. Dark minerals altered to chlorite. Some jarosite is present.

T 20. Isla del Rey. On coast one-half mile west of San Miguel. Basalt. The texture of the groundmass is intergranulate with microlites of labradorite and grains of augite and magnetite. The phenocrysts are of bytownite and augite, the latter being slightly chloritized.

T 56. South of Chiman village. Basalt. Glomeroporphyritic with subophitic groundmass of labradorite laths and grains of augite. Some chlorite.

T 68. Tuenticito—Rio Balsa, Darien. Amygdaloidal basalt. Labradorite microlites and grains of augite in intergranular groundmass. Amygdules are filled with opal and chalcedony.

T 105. Quebrada Ciega. Head of Rio Balsa near Colombian frontier. Basalt. Fairly coarse rock with labradorite and augite in the groundmass and bytownite and augite in phenocrysts. Intrusive (?).

T 107. Rio del Oeste—Altos de Aspave—Colombian frontier. Basalt. Similar to T 105.

T 117 Rio Aretí tributary of Rio Balsa—Darien. Basalt. Rather coarse grained with subophitic texture. Possibly intrusive.

In the Canal Zone, MacDonald found Ancon Hill to be a rhyolite plug and called it, and other plugs and sills of basalt, probably Miocene. In Chiriquí Province andesite occurs in the form of flow rocks at the top of the lower Miocene underlying the middle Miocene, considered by Woodring and Olsson (personal communication) to be the equivalent of the Gatun. This condition is well exposed along the Rio David about six miles north of David and about two miles farther north in a hill east of the river, where the stratigraphic position of the andesite flow was confirmed by drilling operations. About 15 miles east of David, the Galera de Choreha, a flat-topped hill, is capped by andesite overlying lower Miocene shales. In Bocas del Toro Province, along the shore of the Chiriquí lagoon and on several islands of the lagoon, the Gatun lies upon andesite which is probably younger than the lower Miocene, although the complete sequence is not always present, and the Gatun lies directly on the basement andesite on the flanks of the cordillera to the south, by reason of overlap beyond the inner margin of the lower Miocene. It seems fairly certain, however, that vulcanism was widespread at the close of lower Miocene time,



taking the form of tuffs and flows in western Panama. Dikes are especially common in the Pearl Islands where they cut the shale series which forms most of the northwestern part of the group. While the fauna of these foraminiferal shales has not been determined, their stratigraphic position and lithologic resemblance to the upper Oligocene of the mainland leaves little doubt as to their age. They may also include some lower Miocene. On Isla Chepillo at the mouth of the Bayano River, no igneous appears at the surface, but the shales are baked to a hard argillite, and the dome structure, together with the baking, indicates the presence of an igneous plug at no great depth. Numerous plugs, dikes, and sills break through the Oligocene and lower Miocene of the coastal plain from David to Penonomé, while on the Canal Zone their number and irregular distribution is mainly responsible for the irregular topography noted by Hill and others. Owing to the lack of later sediments than lower Miocene in much of the coastal plain, this period of igneous activity can not be dated more precisely. Along the Costa Rica border north of Breñon, boulders of andesite occur lying on the surface of the peneplane cut across the outcrop of the Oligocene and lower Miocene shales, and accumulate at the bottoms of the ravines and stream courses. Their source is unknown, but they may have come from a mid-Miocene flow like that observed near David, or they may be of later age.

Pleistocene vulcanism is represented by El Barú (Volcan de Chiriquí), by Cerro Santiago, and presumably by a similar volcanic cone at El Valle, about 40 miles west of the Canal Zone. Although much smaller than El Barú, the El Valle cone is topographically similar, with smooth slope drained by radiating box canyons, which have developed few laterals, and are obviously very young. Like El Barú, it lies on the south side of the continental divide and close to it, and apparently close to the contact of the Tertiary sediments with the basement rocks. A single crater of oval shape, about four miles on the longer diameter, is floored by lake deposits and drained by a tributary of the Rio Anton through a narrow canyon at the southwest end. The wall rocks are rhyolite.

In the Gulf of Panama, off Chame Point, a group of islands of which the largest are Otoque, Boná, and Estivá, enclose a caldera-like circular area resembling that formed in the Sunda straits by the explosion of Krakatoa in 1883. Otoque, the largest of the group, is composed of andesite, apparently a part of the basement rocks, surmounted at the north side by a ridge of bedded white chert and the remnants of Eocene limestones. The andesites continue to the south side of the island, where they front the supposed caldera, on the south

side of which, a few miles away, is Boná, a steep hill about 650 feet high composed of steeply dipping, nearly vertical ash and tuffs. Estivá on the west and a few smaller islands occupy intermediate places on the supposed former rim. A small plug of light-colored rock stands at the north foot of Boná, and a specimen from this and from a large bomblike mass at the crest were sectioned for microscopic examination. Isotoff's report on them is as follows:

T 46 and T 47. Isla Boná. Indeterminable in sections—fine-grained quartz rocks with chlorite, leucoxene, magnetite, and sericite. Possibly altered andesite.

There is no means of determining the date of formation of this caldera, if such it is, but it might reasonably be considered as contemporaneous with the dikes and plugs in the Pearl Islands, some 35 miles away.

At various points along the shores and on the islands in San Miguel Bay in Darien Province, thin-bedded tuffaceous shales, some carrying foraminifera and some of them barren, are encountered in thicknesses running into thousands of feet. Neither the top nor bottom of the section is exposed, but the only other rocks exposed in the adjacent mainland are andesitic flows and agglomerates, supposedly belonging to the basement complex. These tuffs and shales have been considered to belong to the Oligocene from their lithologic resemblance to the known Oligocene near the Canal Zone and in the region of Chepo. A slide made from a specimen taken at the mouth of the Rio Cucunati was reported by Isotoff thus:

T 62. Ensenada Cucunati. Tuffaceous shale. Tests of forams, crystal fragments and shards of glass.

Another from Rio Taimití:

T 63. Tuff. Devitrified tuff with andesitic and crystal fragments.

It would appear from Isotoff's report as well as from field observation, that the only regional difference is the absence of andesite from the basement rocks near the Colombian border in Darien where nothing but basalt was found.

### METAMORPHIC ROCKS

True metamorphic rocks are rare in Panama. Gneiss has never been reported. The writer has seen schist on the Rio Marea, a few miles above the village of that name in Darien and as float in the

upper Rio Congo, also in Darien. Slate occurs in central Los Santos Province, and near the south coast of the Azuero Peninsula west of Morro Puercos; and on the Rio Diquis in southern Costa Rica, 35 miles west of the Panama border. All these outcrops are small. Argillite, apparently caused by baking of shale by flows or sills, occurs near Morro Puercos; on the head of Rio Chiriquí north of Caldera; in the Burica Peninsula on the upper Rio Blanco; and near Golfito in southeastern Costa Rica. It occurs commonly as boulders or gravel in the Rio Chiriquí Viejo, and in the Pleistocene conglomerate near Puerto Armuelles. No metamorphic minerals are developed in it; much of it might be called simply baked shale. There are many places where Oligocene and Miocene shales have been baked by intrusive sills and dikes, but in most cases the effect is limited to a few inches, rarely more than a foot from the contact. It is possible that some of the argillite boulders have come from such occurrences; however, the argillite outcrops described above are in the basement complex; they are pre-late Eocene, perhaps Cretaceous. Woodring and Thompson (1949) speak of "indurated fine-grained sediments that were probably originally fine-grained tuffs," which occur in the basement complex of the Canal Zone. These are probably of the same period as the argillites described above.

Near the Rio Ocones on the south coast of Veraguas west of Morro Puercos, there are also black shales which are not indurated, but which do not resemble the Tertiary sediments of the region. These unaltered rocks also appear to belong to the basement complex of Veraguas. There is also a small outcrop of marble farther east.

In general, the basement complex is extrusive volcanics, flows, agglomerates, and tuffs, showing much deformation, but little metamorphism, and predominantly basic. The sedimentaries or altered sedimentaries included with the lavas are probably not older than Cretaceous. Some of them may be early or middle Eocene.

### SEDIMENTARY ROCKS

At many places, mostly in Darien from the Sabana River westward; on certain islands in the Gulf of Panama; at Bahia Honda on the south coast of Veraguas; and on the Burica Peninsula, there is found a stratified white, gray, blue, or green chert, which lies on the volcanics of the basement complex where its base is seen, and underlies the Eocene limestone. In the Rio Sabana-Rio Congo area of Darien, it is in some places interbedded with tuffs, but in general it appears to be a separate unit. No fossils have been seen in it, and its age is unknown. Olsson (1942) thinks it may be the equivalent

of the Guayaquil chert of Ecuador, which has been assigned various ages from late Cretaceous to middle Eocene. It has been thought to be a chemical deposit, associated with submarine eruptions.

### CRETACEOUS

Although no description has been published, it is known that Cretaceous foraminifera have been found in northwestern Panama. It is also possible that the argillites mentioned under Metamorphic Rocks are of that age.

### EOCENE

The oldest fossils described from Panama, according to Olsson (1942), are of late Eocene age and belong to the Búcaru formation of Los Santos Province in the Azuero Peninsula. The rocks outcrop near Punta Búcaru near the mouth of the Tonosí River, and underlie the Tonosí valley, a fault basin about 15 miles wide and 35 or more miles long in the south-central part of the peninsula. The exposed thickness approximates 2,000 feet, according to Olsson, and it seems probable that it originally covered a much larger area on both sides of the basin. Small exposures of Eocene occur along the east shore of Montijo Bay on the west side of the peninsula. The Azuero Peninsula Eocene is the only known outcrop of that age between the Canal Zone and David, a distance of some 180 miles, although Eocene may be concealed beneath younger rocks at some intervening points.

The Búcaru formation begins with a volcanic breccia containing worn fossil fragments, and with a limey cement. The large angular volcanic fragments continue upward for some distance in the lower part of the formation, indicating that the beginning of the invasion of the sea was contemporaneous with the last phase of Eocene vulcanism. Following the fossil-bearing conglomerates are blue-green or black shales with thin sandstone beds, with a total thickness of about 1,500 feet, and these are followed by about 500 feet of blue coarse sandstones and sandy yellow limestones. This last section carried a fauna mainly of foraminifera, while in the middle and lower parts of the formation the fauna is mainly molluscan, and Olsson considers it to be the oldest Eocene of Panama, equivalent to the Talaran, the lower late Eocene of Peru. Typical fossils from this part of the section are listed by Olsson as: *Aturia peruviana* Olsson, *Venericardia tonosicensis* Rutsch, *Noctiopsis woodringi* MacNeil, *Ractomya* sp., *Spisula* sp., *Tellina* sp., *Cardium* cf. *samanicum* Olsson, *Conus* cf. *peruvianus*

Olsson, *Lyria* sp., *Clavilithes* sp., *Xancus* cf. *peruvianus* Olsson, and *Harrisonella* cf. *peruviana* Olsson.

From the upper part, *Lepidocyclus panamensis* Cushman was collected by MacDonald, with a still higher horizon containing *Operculina* and echinoids. Olsson believes this horizon to be separated from the *Lepidocyclus* beds by an unconformity. From collections by Olsson and Terry from the upper section, Vaughan (personal communication) identified *Pseudophragmina* (*Proporocyclus*) cf. *P. flintensis* Cushman, *Operculinoides*, *Carpenteria*, *Gypsina*, *Helicostegina* sp., apparently *H. soldadensis* Grimsdale, and *Lepidocyclus* (*Pliolepidina*) *panamensis* Cushman, A and B forms.

The Canal Zone Eocene is described by Woodring and Thompson (1949) as beginning with 1 to 3 feet of conglomerate, followed by 25 feet of medium to fine-grained sandstone, the upper part of which is silty. Above this, the formation is made up of mudstone and siltstone, which carries lenses of limestone, mostly thin, but in some places reaching a maximum of 300 feet. The limestone lenses carry orbitoidal foraminifera, including *Lepidocyclus chapteri* and *L. cf. pustulosa*. Woodring and Thompson (1949) give the Eocene of the Canal Zone the name Gatuncillo formation and consider it to be the equivalent of the Eocene of the Madden Lake basin described by Reeves and Ross (1930) under the name Bohio. Reeves and Ross were not immediately concerned with Eocene stratigraphy and indicated only that it is divisible into two parts, "a thick series of hard thin-bedded fossiliferous limestone at its top, the rest of the formation consisting largely of soft shale and clay, interbedded with lenses of similar limestone. In addition, there is at the base a conglomerate consisting largely of volcanic boulders." Embich later collected from the shale of Reeves and Ross' lower division a fauna of small foraminifera described by Coryell and Embich (1937), who gave the formation the name, Tranquilla shale. This name is discarded by Woodring and Thompson (1949) because the type area is now covered by the waters of Madden Lake, and no longer accessible. Coryell and Embich describe a fauna of 46 genera and 64 species which they correlate with the McElroy division of the Jackson (upper Eocene) of the United States, "because of the presence of a variety of *Textularia hocklyensis* which is a guide to the McElroy, and the characteristic species, *Dentalina jacksonensis*, *Eponides jacksonensis*, *Haplophragmoides dibollensis*, and *Robulus alato-limbatus*." From the limestones overlying the shale of the Madden Basin Olsson and Terry collected a fauna of orbitoidal foraminifera, which were studied by Vaughan (personal communication). They include: *Camerina striatoreticulata* Rutsch, *Carpenteria*, *Discocyclus*

*georgiana* Cushman, *D. mariannensis* Cushman, *D. cf. D. minima* Cushman, *D. (Astero cyclina) asterisca* Guppy, *Eodictyoconus*, *Amphistegina* cf. *A. cubensis* Palmer, *Gypsina globulus* Reuss, *Heterostegina*, *Lepidocyclina pustulosa* forma *tobleri* H. Douvillé, *L. duplicata* Cushman A and B forms, *L. macdonaldi* Cushman, *L. (Nephrolepidina)* A form, *L. (Nephrolepidina) panamensis* Cushman, A and B forms, *L. (Nephrolepidina) chaperi* Lemoine & R. Douvillé, and *Operculinoides* cf. *ocalanus* Cushman. The rock contains an abundance of *Lithothamnium*.

On the Rio Gatuncillo, near the village of New San Juan, Olsson and Terry collected specimens identified by Vaughan: *Eodictyoconus*, *Cibicides*, *Carpenteria*, *Camerina*, *Operculinoides ocalanus* Cushman, *O. soldadensis* Vaughan and Cole, *Heterostegina*, *Discocyclina (Astero cyclina) georgiana* Cushman, *Discocyclina mariannensis* Cushman, *Gypsina globulus* Reuss, *Amphistegina* cf. *A. cubensis* Palmer, *Lepidocyclina duplicata* Cushman A and B forms, *L. pustulosa* H. Douvillé, and *L. macdonaldi* Cushman.

The Madden dam basin is outlined by faults striking N. 70° E., which enclose an area some 14 miles wide and 25 miles long, including the Canal Zone areas of the Gatuncillo formation. There is reason to believe that the original area of marine Eocene was considerably larger. The N. 70° E. system of faults is intersected by another set striking N. 25° E. to N. 30° E., and at the east end of the basin, there are fault contacts at various places which bring the higher members of the Eocene formation into contact with the basement complex. Owing to the difficulties occasioned by deep weathering and heavy jungle cover, it is not easy to determine the presence, much less the amount of displacement in these faults. However, south from the mouth of Rio Chagres in Madden Lake to the continental divide, the Eocene shales (Tranquilla or Gatuncillo) are apparently missing, whether by faulting or overlap of the limestone section. On the continental divide between the heads of Rio Enrique and Rio Chilibrillo, the orbitoidal limestone lies directly on the andesite of the basement complex. From specimens collected here and submitted to Vaughan, the following were identified: *Eodictyoconus*, *Camerina*, *Heterostegina*, *Gypsina*, *Lepidocyclina* cf. *L. duplicata* Cushman, *Discocyclina* cf. *D. minima* Cushman, and *Lepidocyclina (Nephrolepidina)* cf. *L. chaperi* Lemoine & Douvillé

Here there seems to be no doubt about the overlap of the limestone beyond the limits of the shale.

In the foothill belt on the south flank of the continental divide, the orbitoidal limestones continue to the east of the Madden Basin,

but Eocene has not been identified until the vicinity of Chepo, about 35 miles east of Panama City, is reached. Here on Rio Mamoni, the writer collected the following, identified by Vaughan: *Operculinoides*, *Gypsina*, *Lepidocyclina pustulosa* H. Douvillé. On the road east from Chepo to El Llano: *Eodictyoconus*, *Carpenteria*, *Gypsina*, *Operculinoides*, *Discocyclina minima* Cushman, *D. (Astrocyclina) asterisca* Guppy, *Lepidocyclina macdonaldi* Cushman, *L. pustulosa* H. Douvillé. On Rio Terable: *Operculinoides* 2 spp., *Discocyclina (Astrocyclina)* cf. *D. asterisca* Guppy, *Pseudophragmina (Proporocyclina)* sp., *Lepidocyclina (Pliolepidina)* sp., *Helicostegina* sp. close to *H. soldadensis* Grimsdale. At Peña Tiburon on Rio Bayano above El Llano, were collected *Operculinoides*, *Lepidocyclina* cf. *pustulosa* H. Douvillé, B. form, and *L. macdonaldi* Cushman. At La Bóbida on Rio Paja, a tributary of Rio Bayano, *Camerina*, *Operculinoides*, and *Lepidocyclina macdonaldi* Cushman. In the Chepo-El Llano region the limestones are lenticular and on Rio Platanal, Rio Uní, and Rio Terable, small tributaries of the Bayano, clays and marls with occasional coarse sandstones form the bulk of the formation in which a crustacean (*Zanthopsis terryi* Rathbun), and some small mollusks, notably *Ampullina* cf. *depressa* Lamarek, and *Potamides* are common. Volcanic tuff and ash overlie these beds and the transition to Early Oligocene takes place in these tuffs.

The Eocene outcrop continues eastward and has been seen by the writer as far east as Rio Tabardí, about 25 miles east of El Llano; and it is known to exist above the mouth of Rio Ibertí, about 10 miles farther east. Between this point and Rio Chatí in the province of Darien, no exploration has been permitted by the Cuna Indians, but the orbitoidal limestone reappears on the Chatí and continues along the flank of the continental divide to Rio Paya, on the Colombian boundary near the head of Rio Tuira. It also occurs in Darien Province on both sides of the Cerro Pirri, on Rio Sanson, Rio Conglon, Rio Aretí, Rio Cucunatí, and Rio Sabana in central Darien Province, on Rio Congo, and in the valley of Rio Sambú near the Pacific coast. On the coast it has not been discovered.

In central Darien Province, on Rio Pihuila, a tributary of Rio Balsa, the formation is a sandy shale and sandstone, with *Potamides* and *Hemisinus*. On Rio Coreona, a tributary of Rio Chico, in Chucunaque drainage, the base of the Eocene is a dark shale with sandstone layers, carrying *Lepidocyclina* cf. *chaperti*. In general, however, the Eocene of Darien consists of hard, crystalline limestone with, in the larger part, included volcanic matter, which locally runs to hundreds, in some cases thousands of feet in thickness. On Quebrada Los

Nunos, a tributary of Rio Sabana, the thickness of the combined agglomerate, conglomerate, and limestone exceeds 4,850 feet, of which about 1,650 feet is in the coarse volcanic elasties and interbedded limestone lenses of the lower part, and about 600 feet of finer tuffs and limestones, the uppermost 2,600 feet being thin- to medium-bedded limestone with not much noticeable volcanic material. The base of the section rests on well-bedded greenish chert, much deformed and twisted. No fossils were collected, but it appears that the lower and middle sections correspond to the Eocene and that the upper part may be Oligocene.

On the Tupisa and Despreciado of the Chucunaque, the Eocene begins with 850 + feet of dark shale and shaly sandstone carrying orbitoids, followed by 2,540 feet of agglomerates, with a few thin sandstones and conglomerates; and above the agglomerates, 220 feet of clay, 420 feet of sandstone and sandy shale, 430 feet of limestone, 320 feet of sandstone and shale, and 900 feet of limestone and calcareous sandstone— a total of 5,580 feet which includes an unknown amount of Early Oligocene, probably not over 1,000 feet. No such thicknesses of Eocene, and no such amount of interbedded volcanics are known elsewhere in Panama. Evidently Late Eocene vulcanism was much more vigorous in Darien than in central or western Panama.

On Rio Congo a section exceeding 1,000 feet in thickness consists mainly of coarse agglomerate, some boulders reaching 8 to 10 feet in diameter, with a matrix of finer tuffaceous material. In this agglomerate appear occasional lenses of orbitoidal limestone. Here as in Los Santos, the last of the great Eocene volcanic activity coincides with the beginning of marine sedimentation.

In western Panama, recognized Eocene begins three miles north of David, the capital of Chiriquí Province. This is about 100 miles west of the nearest Eocene, on the shore of Montijo Bay. The intervening sedimentary area of Chiriquí and Veraguas is surfaced with Oligocene and Miocene, and the Eocene may underlie them, but is not known to outcrop.

The well-known David Eocene exposure near km. 12 on the Chiriquí National Railway is in a much-faulted area with tepid sulfur springs which have created a swamp surrounding the small outcrop of orbitoidal limestone from which *Lepidocyclina panamensis*, *L. duplicata*, and *L. macdonaldi* have been identified. Farther west, for a distance of five or six miles, a more complete section is exposed on various tributaries of Rio Platanal; and near the Costa Rica border, on the Rio Blanco de Breñon, a small tributary of the Chiriquí Viejo, an apparently complete section of late Eocene can be seen in the axial



part of a large antiline. Three limestone beds, separated by coarse barren sandstones, yielded the following (identifications by Vaughan): Basal bed (lying on andesite)—*Eodictyoconus*, *Camerina*, *Heterostegina*, *Discocyclina* sp. near *D. minima* Cushman, *Lepidocyclina* 2 spp.

Bed 2—*Discocyclina* sp., *Lepidocyclina trinitatis* (?), *Lepidocyclina* (*Nephrolepidina*) sp., *Lepidocyclina* sp. Possibly a fourth species of *Lepidocyclina*.

Bed 3—*Lepidocyclina trinitatis* (?) and *L. (Nephrolepidina)*.

Above Bed 3 is another barren sandstone and then a conglomerate with lime cement, carrying *Lepidocyclina gigas* and marking the base of the Oligocene.

Twenty miles to the south in the Burica Peninsula limestone forms almost the entire thickness of the Eocene. No fossils have been collected, but the tests of orbitoidal foraminifera constitute a large part of the rock which exceeds 100 feet in thickness and rests directly on the andesite, or, in some places, on a thick chert.

On the north side of the continental divide, in Bocas del Toro Province, the limestone includes much volcanic material, but the chert is missing, the limestone lying directly on the andesite. The collected material in the United States National Museum has not been studied, but the fossils resemble those of the Chiriquí Eocene and the correlation is accepted by geologists who have worked in both areas. The Bocas del Toro Eocene extends westward into Costa Rica as does the Eocene of Chiriquí.

The Eocene of the Isthmian region represents an invasion of the sea over a region predominantly volcanic, or in some limited areas with cherts. The limits of this Eocene sea can not be determined with certainty. In eastern Panama, the Eocene sediments are found bordering all the large areas of basement igneous, and small exposures of infolded or unfaulted Eocene can be found within those areas so frequently as to leave little doubt that it once covered the entire province of Darien. West of San Miguel Bay no Eocene is known in Pacific drainage, except the narrow band along the foothills of the continental divide, which ends at the Canal Zone. Eocene is not definitely known in the islands off the Pacific coast, but may be present in small amounts on Isla del Rey.

In central and western Panama, no Eocene occurs in Atlantic drainage between the Canal Zone and the basin of the Changuinola River in Bocas del Toro Province, a distance of more than 200 miles; while on the Pacific side an equal interval is broken only by the outcrop on the Azuero Peninsula. While much of these intervening areas is covered with younger sediments which may conceal Eocene deposits,

it seems unlikely in a country so much folded and faulted and with so many exposures of the basement rocks, that the Eocene could remain unknown if it were present. It is the writer's conclusion that the provinces of Coelé and Veraguas were mostly land areas in Eocene time. The deposition of the late Eocene seems to coincide with the dying phases of a vulcanism of which the greatest activity of the period was in Darien Province around the head of San Miguel Bay. Practically all the Eocene is of shallow water deposition.

#### OLIGOCENE

Oligocene sediments are of two distinct types, marine deposits laid down in waters of moderate depth, and terrestrial deposits, consisting largely of volcanic elastics, with some terrestrial and shallow-water marine sediments. The principal centers of volcanic activity in Oligocene time were the Pearl Islands of Panama Bay (fig. 3), and the shores of San Miguel Bay; and central Panama from the Canal Zone to Montijo Bay. The volcanic elastics occur interbedded with

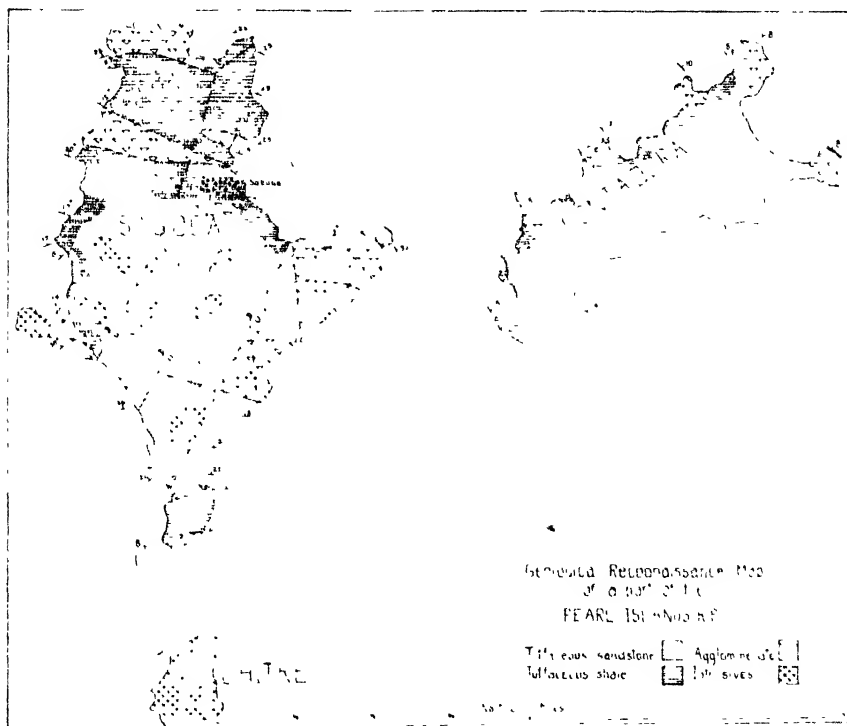


Figure 3. Geological reconnaissance map of a part of the Pearl Islands

marine shales in the former area, and with lignites and other terrestrial deposits in the latter. No satisfactory separation has been made between the Oligocene and the underlying late Eocene, nor between the Oligocene and the overlying early Miocene. In eastern Panama, the base of the Oligocene probably lies near the top of the limestone section, most of which is undoubtedly Eocene, but no collections from this horizon have been studied.

The bulk of the Oligocene in eastern Panama consists of a massive brownish marl with numerous radiolarian spicules and much fine volcanic ash. In the vicinity of San Miguel Bay, the volcanic material is coarser and constitutes the bulk of the formation, but in the Garachiné-Sambú basin, and the Tuira-Chucunaque valley, the radiolarian ooze is more plentiful. In the Sambú valley geologists of the Gulf Oil Company described the Oligocene as "a marly material which is sometimes hard enough to be classed as limestone. Dark gray to brown in color. Many foraminifera, and also radiolaria which have been replaced by calcite. Much organic matter." Below this the section changes to hard calcareous shale and fine dark crystalline limestone, with the Eocene contact undefined. The equivalent Oligocene section in the Tuira-Chucunaque valley is quite similar and has been called the Aruza formation.

In the lower valley of the Bayano River, near El Llano, the Oligocene appears as a yellowish to brownish gray tuffaceous sandstone and sandy tuffaceous shale with limestone lenses from which collections made by Olsson and Terry yielded: *Heterostegina panamensis* Gravell, *Lepidocyclina cancelli* Lemoine and R. Douvillé, and *Miogypsina cushmani* Vaughan. Farther west at Rio Hondo, about three miles west of Chepo, the same assemblage was found, and still farther west at Rio Pacora, a collection by Terry gave *Operculinoides*, *Lepidocyclina* sp., *Nephrolepidina verbecki* H. & H. T. Barker, *Eulepidina* sp. aff. *L. undosa* Cushman.

On the old Spanish trail from Panama to Nombre Dios at Monte Oscuro, a few miles outside the Panama City limit, Olsson collected *Gypsina*, *Heterostegina*, *Miogypsina*, and *Lepidocyclina* sp. cf. *L. miraflorensis* Vaughan. This locality is close to the Canal Zone limit and the formation is largely volcanic material. It probably belongs in the Bohio formation.

In the Zone, Woodring and Thompson (1949) describe the Bohio as massive or poorly bedded conglomerate, tuffaceous sandstone, and tuffaceous siltstone. The coarse constituents of the conglomerate range up to boulders six feet in diameter and coarse and fine matter is mostly basaltic. Much of it is nonmarine, and silicified tree trunks

occur in it. Fossils are rare, but *Lepidocyclina canellei* has been recognized by Stewart from a locality near Darien station on the railroad.

According to Woodring and Thompson in the region of the Gaillard cut the Bohio is replaced by the Bas Obispo and Las Cascadas formations, which are entirely volcanic, consisting of angular and subangular fragments of andesite embedded in tuffs in the Bas Obispo, and waxy and clayey altered tuff in Las Cascadas. The age determination is questionable. West of the Canal Zone, Olsson and Terry, in a traverse from El Valle to Puerto La Tagua, at the southwest corner of Gatun Lake, passed over a ten-mile stretch of volcanics, lava flows, agglomerates, tuffs, and ash. A rude bedding could occasionally be seen, the dip being generally northward at a low angle. Near the Rio Esterial terrestrial sediments appear, including coal. No fossils have been collected from the coal-bearing section, but it is believed to be the equivalent of the lower Caimito, which Woodring and Thompson (1949) consider early Oligocene in the adjacent Canal Zone area. The entire region from the Canal Zone westward seems to have been a volcanic island in Oligocene time. The Canal Zone includes the fringe of these eruptive rocks, where they interfinger with sediments, in some places marine, in other places terrestrial. This band of interbedded sediments and volcanics extends westward to about 80' 45' on the Caribbean coast. It is hard to draw a contact, for the inner edge of the sediments which are thus interbedded, as the line is undoubtedly extremely irregular and could only be mapped after thorough detailed field work. The writer made a trip up the Rio Coelé del Norte to the mouth of the Rio Toabre and from the canoe could see no outcrops along the river other than the volcanics, but sedimentary beds are present, as samples shown him along the way included foraminiferal shales which had been baked at the contact with andesitic lavas. From the air the region has the parallel-ridged appearance of an area of tilted sediments.

In the Quebrancha syncline, east of the Canal Zone, Woodring and Thompson (1949) divide the Bohio into a gritty sandstone lower member and a volcanic upper member.

The late Oligocene of the Canal Zone is largely missing on the Pacific coast and as far north as the Gaillard cut, but includes the Culebra formation which is limited to the Gaillard cut and the immediate vicinity. The age of the formation is a matter of dispute among paleontologists, depending on personal opinion regarding the diagnostic importance of the lepidocycline species which in California and the Canal Zone occur in the fossil assemblage which would otherwise be regarded as Miocene; while in European and Atlantic coast

faunas, their presence is considered proof of Oligocene age. The Culebra is placed by Woodring and Thompson at the top of the Oligocene, but the larger part of the late Oligocene is missing, the Culebra resting on the Las Cascadas agglomerate. The Emperador limestone is in the upper part of the Culebra, including the transition to definite early Miocene. It is a light-colored, occasionally marly limestone, apparently reefs, which are not continuous over more than a few miles, and often much less so. Vaughan (1918) notes the evidently contemporaneous faunas of the Emperador and Culebra with the Antigua Oligocene. The patchy occurrence of the Emperador has led to confusion between it and other limestones.

On the Caribbean side of the Canal Zone, the late Oligocene is included in the Caimito formation. Near the Darien radio station on the railroad, the type section includes a basal conglomerate, which is considered by Woodring and Thompson to be of Las Cascadas age. The conglomerate consists of basaltic cobbles in a sandstone matrix containing acidic tuff. The remainder of the formation in this locality is divided into a lower member chiefly tuffaceous sandstone, with thin limestone lenses, and a thicker upper member composed of tuff, agglomeratic tuff, tuffaceous siltstone, and sandy tuffaceous limestone lenses. The basal conglomerate is not fossiliferous, but in the lower member *Lepidocyclus cancelli*, *L. vauhani*, and other larger foraminifera occur, as also do corals. The upper member is less fossiliferous, but carries *Lepidocyclus cancelli*.

In the Quebrancha syncline just west of the Madden Dam basin, Woodring and Thompson (1949) divide the Caimito into two members, the Quebrancha limestone overlying the Bohio without unconformity, and an overlying calcareous siltstone member which includes some sandstone, while in the Madden Dam basin itself, they give the Caimito a five-fold division, of which the three upper members are placed in the early Miocene. The late Oligocene portion consists of a calcareous sandstone member resting on the Bohio and an overlying pyroclastic member containing a thick limestone lens carrying *Lyropecten condylomatus*.

The same authors consider the entire Bohio of Reeves and Ross (1930) as probably belonging to the Gatuncillo (Eocene), but from a collection by Olsson and Terry in 1933, in the area now covered by Madden Lake between the mouth of Rio Pequení and Rio Puente, Vaughan identified *Lepidocyclus (Eulepidina) farosa* Cushman, and placed it in the Oligocene; Embick (personal communication) also collected *Lepidocyclus gigas* from a nearby outcrop. Apparently the upper part of Reeves and Ross's Bohio is actually Oligocene.

In general, the Canal Zone Oligocene is terrestrial and mainly volcanic on the southwest side and increasingly marine in character as one goes northeastward through the Madden Dam basin, suggesting that there may have been an eastward outlet to the sea, which was cut off by the mid-Miocene uplift and deformation. West of the Canal Zone and south of the continental divide, rocks of volcanic origin predominate for some 20 miles or more to the vicinity of Capira; between Capira and the coast an area of coal-bearing sandstone and shale has been reported. The writer has not examined this area, but it seems probable that the coal is of the same age as the Rio Indio coal which occupies a similar stratigraphic position on the other side of the divide. Vaughan (1918) states:

Dr. MacDonald collected fossil plants at Sta. 6840, about seven miles northeast of Bejuca, near Chame, Panama, in a yellowish argillaceous sandstone that seems to overlap conglomerates and is believed to represent the Calmito formation. Professor Berry records the following species from this locality:

*Guatteria culebrensis* Berry, also Culebra and Gatun formations.

*Hirca oligocaenica* Berry.

*Hieronymia lehmanni* Berry

*Schmidia bejuensis* Berry, also Culebra. As two of the four species also occur in the Culebra formation, it appears that the formation in which they were obtained is in age near the Culebra formation.

It is not known whether these coals are Oligocene or early Miocene, but they appear to be definitely older than the coal of the Gatun formation in Costa Rica, Bocas del Toro, and Chiriquí. The coal-bearing sandstones outcrop at several places in, and on the borders of the Santiago plain, and the rocks in which they occur carry large amounts of volcanic ejecta, flows, tuffs, and ash.

South of the Santiago plain, on the east side of Montijo Bay, on Rio Mariato, Condit collected *Ampullinopsis* cf. *spenceri* Cooke, from a shale overlying sandstones and conglomerates (Olsson, 1942). In the United States National Museum, collection 7962 contains *Turritella* cf. *venezuelana*, *Nassa*, *Xancus*, *Pitaria*, and *Balanus*, and Olsson considers it middle or late Oligocene (personal communication). Collection 8467 from nearby contains *Crassatella* cf. *berryi*. Olsson correlates the shale with the middle Oligocene of northern Peru and with the Oligocene of Antigua, and places the underlying Montijo formation as the equivalent of the Bojio. The coal-bearing sandstones of the Santiago plain thus would fall into late Oligocene classification, although here as elsewhere in Panama, no sharp contact can be drawn between the late Oligocene and the early Miocene. The

volcanic land area of Oligocene time apparently continued as far west as the head of Montijo Bay, and probably farther. The Oligocene island of central Panama was fringed by a low swampy coastal region, on the surface of which shallow marine and terrestrial sediments were mingled with the ejecta from the volcanic island.

West of Montijo Bay, the Soná Peninsula is composed of igneous rocks which the writer believes belong to the basement complex, from the presence of stratified chert at Bahía Honda (L. G. Hertlein, personal communication). Stratified chert is known in Panama only below the late Eocene. Near the lower course of Rio Tabasará about 20 miles west of Soná, coarse tuffaceous sediments with interbedded lavas and volcanic clastics of various sizes reappear. The formation has not been studied and its age is uncertain, but at least a part of it, if not all, is accepted as Oligocene by most geologists who have seen it. There are no collections from this area, but United States National Museum collection 6534, from a locality some miles north of San Felix, contains *Glyptostyla* cf. *panamensis*, which suggests late middle or late Oligocene to Olsson (personal communication). The outcrop covers a belt 10 to 15 miles wide across Chiriquí Province to the eastern edge of the Pleistocene volcanics west of the David River, and becomes finer grained westward. At the railroad line from David to Boquete, which is close to the eastern edge of the Pleistocene volcanics, the formation is a hard shale with considerable ash but no coarse tuffs. The hardness is probably due to baking by crypto-vulcanism in mid-Miocene time, as the region for miles around is cut by dikes and plugs; and thick lava flows appear at, or close to, the contact between early Miocene and middle Miocene. The Pleistocene volcanics cover the region westward to Rio Chiriquí Viejo, near the Costa Rica border, where the Tertiary sediments reappear. Here the Oligocene begins with a conglomerate bed lying on late Eocene sandstone. The conglomerate is cemented with lime and carries *Lepidocyclus gigas* and is followed by a shale section, then by two beds of limestone separated by shale. The lower limestone bed carries a large selliform *Nephrolepidina* and the upper one has the same species and also *Eulpidina undosa* (Vaughan, personal communication). In the shale a little above these limestones are what appear to be specimens of *Nummulites*, but identification is not complete as the material collected disappeared in transit. The shales continue with numerous exposures for a distance of 10 miles or more. They are usually gray in color and carry numerous foraminifera, larger fossils being rare. They resemble closely the Uscari shale of Bocas del Toro and Costa Rica and like the Uscari, probably include middle and late Oligocene and

early Miocene. In 1925 a well was drilled near David which began in a lava flow of middle Miocene age, passed through some 150 feet of lava, and an equal amount of Gatun sandstone and entered the shale. No faunal record is available, but the writer has been informed that the well passed directly from the Gatun into the Oligocene, no early Miocene being found. There may be involved here the question of diagnostic species, which is often a matter of dispute in the Isthmian region. No Oligocene has been recognized on the Burica Peninsula.

On the Caribbean side the Uscari has been studied by Olsson (1922) from surface outcrops, and a considerable fauna has been determined from well cuttings. As this faunal record has not been published, it is included with the permission of the Sinclair Panama Oil Company. Foraminifera from well on Columbus Island, Bocas del Toro, R.P. (to depth of 7,790 feet):

*Amphistegina lessona* d'Orbigny

*Anomalina* sp.

*Bolivina acuariensis* (Costa)

*Bolivina floridana* Cushman

*Bulimina bleekerii* Hedberg

*Bulimina marginata* d'Orbigny

*Candorbulina univrsa* Jedlitschka

*Cassidulina subglobosa* Brady

*Chilostomella oolina* Schwager

*Chilostomella oricula* Nuttall

*Cibicides mexicana* Nuttall

*Cibicides* sp.

*Clavulina cyclostomata*

Galloway and Morrey

*Clavulina venezuelana* Nuttall

*Cyclammina cancellata* Brady

*Cyclammina* sp.

*Dentalina* sp.

*Discorbis bertheloti* d'Orbigny

*Ellipsenodosaria tenuiculi* d'Orbigny

*Entosolenia marginata* Montagu

*Epistomena elegans* d'Orbigny

*Eponides parantillarum*

Galloway and Heminway

*Gaudryina jacksonensis* Cushman

*Glandulina lacrigata* d'Orbigny

*Globigerina bulloides* d'Orbigny

*Globigerina triloba* Reuss

*Globorotalia* sp.

*Globobulimina pacifica* Cushman

*Gyroidina soldanu* d'Orbigny

*Haplophragmoides* sp.

*Heterostomella cubensis*

Palmer and Bermudez

*Marginulina basispinosa*

Cushman and Renz

*Marginulina subaculeata*

(Cushman)

*Marginulina wallacei* Hedberg

*Marginulina* sp. "A"

*Nodosaria carinata* d'Orbigny

*Nodosaria longiscata* d'Orbigny

*Nodosaria raphanistrum* (Linne)

*Nodosaria vertebralis* Batsch

*Nomion soldanu* (d'Orbigny)

*Pencrophi* sp.

*Plectonodularia californica*

Cushman and Stewart

*Planulina* sp.

*Pseudoclavulina mexicana* Cushman

*Pullena bulloides* d'Orbigny

*Pyrgo murrhyna* Schwager

*Quinqueloculina lamarkiana*

d'Orbigny

*Robulus calcar* Linne

*Robulus cultratus* Montfort

*Robulus formosus* Cushman

*Robulus oblongus*

Coryell and Rivero

*Robulus* sp. "B"

*Rzhekinia* sp.

*Sigmolima* sp.

*Sigmolima schlumbergeri*

A. Silvestri



<i>Siphonina tenuicarinata</i> Cushman	<i>Textulariella</i> sp.
<i>Siphogenerina transversa</i> Cushman	<i>Trochammina</i> sp.
<i>Sphaeroidena variabilis</i> Reuss	<i>Uvigerina gardnerae</i> Cushman
<i>Sphaeroidinella dehiscentis</i> (Parker and Jones)	<i>Uvigerina pygmaea</i> d'Orbigny
<i>Spiroloculina alveata</i> Cushman and Todd	<i>Uvigerina rustica</i> Cushman and Edwards
<i>Textularia mexicana</i> Cushman	<i>Verneuilina</i> sp.

In addition, Palmer (1923) determined the following species from Nigua Creek, Panama [erroneously cited as Costa Rica in her account]:

<i>Nodosaria soluta</i> Reuss	<i>Nummulites costaricensis</i> (Palmer)
<i>Cristellaria cultrata</i> Montfort	<i>Vaginulina legumen</i> Linnaeus
<i>Cristellaria reniformis</i> d'Orbigny	
<i>Fronicularia</i> sp.	

Porter (1942) collected from Amoura River, just above the mouth of Uscari Creek, the following additional species (determinations by P. P. Goudkoff):

<i>Bolivina acerosa</i> Cushman	<i>Marginulina subbullata</i> Hantken
<i>Bolivina pisciformis</i> Galloway and Morrey	<i>Nodosaria eicaldi</i> Reuss
<i>Bolivina rinconensis</i> Cushman and Laiming	<i>Nodosaria holserica</i> Schwager
<i>Cassidulina crassa</i> d'Orbigny	<i>Nodosaria koina</i> Schwager
<i>Cassidulinoides</i> sp.	<i>Nodosaria camerina</i> Dervieux
<i>Cibicides</i> cf. <i>ungeriana</i> d'Orbigny	<i>Planulina cushmani</i> Barbat and von Estorff
<i>Clavulina communis</i> d'Orbigny	<i>Robulus barbati</i> Cushman and Hobson
<i>Dentalina</i> cf. <i>D. communis</i> d'Orbigny	<i>Robulus mayi</i> Cushman and Parker
<i>Dentalina multilincata</i> Bornemann	<i>Robulus</i> cf. <i>tactowata</i> Stache
<i>Dentalina roemeri</i> Neugeboren	<i>Saracenaria acutauricularis</i> Fichtell and Moll
<i>Eponides umbonata</i> Reuss	<i>Textularia mississippiensis</i> Cushman
<i>Globigerina conglomerata</i> Schwager	<i>Uvigerina</i> cf. <i>gardnerae</i> Cushman and Applin
<i>Lagena striato-punctata</i> Parker and Jones	<i>Uvigerina hispida</i> Schwager
<i>Lamarckina</i> sp.	
<i>Liebusella pozonensis</i> var. <i>crassa</i> Cushman and Renz	

This collection is from a section believed to be stratigraphically lower than that at the oil seep on Uscari Creek. According to Porter, 15 of the species are to be correlated with the lower Miocene, and 9 with the upper Oligocene. Porter proposes the name Amoura shale for the section represented, leaving the question of member or formation status for future determination.

The Uscari represents the climax of a long period of erosion, begin-

ning in late Eocene time and continuing with only minor and short-lived regressions to mid-Miocene. At the end of the period, the land of the present isthmian region must have been reduced to a group of islands of a total area not exceeding one-half its present size—perhaps much smaller. The total deposits of Oligocene and late Miocene times are 5,000 feet thick or more over great areas and have a total mass which seems to demand as a source a land area of much greater size than the present isthmus. Although volcanic material is present throughout, the bulk of the Oligocene and lower Miocene consists of limy shales with considerable bituminous content. It appears to the writer that the presence of a considerable land area both on the Caribbean and Pacific sides in regions now submerged must be assumed for the greater part of the Oligocene and for much of the lower Miocene.

The Uscari is separated from the overlying middle Miocene by a sharp erosional unconformity over most of the region. However, on Columbus Island, Bocas del Toro Province, the overlying middle Miocene is a shale with limestone lenses, with no basal conglomerate or other lithologic indication of prolonged erosion. A well started in lower Miocene beds was abandoned at 8,640 feet without encountering any significant change of formation. The bottom was in middle Oligocene. According to the paleontologist the faunal record indicates that the well passed through two thrust faults and perhaps three, so that no accurate estimate can be made of the true thickness of the formation. Estimates from measurements of surface outcrops are subject to error arising from lack of continuity of exposures, and especially from the presence of faults, often unrecognized by field geologists.

In the valley of the Reventazon River in Costa Rica, Branson (1928) estimated 5,000 feet of Oligocene and early Miocene without reaching the bottom of the section. This locality is about halfway between Puerto Limon on the Caribbean coast, and the continental divide. Branson's Uscari is mainly sandstones and conglomerates, with two thick limestone members, while the Oligocene, though predominantly shale, also has several thick sandstones, some thin conglomerates and several limestone beds. The whole series has a decidedly shallow-water aspect as compared with the deep-water rocks of the same age in Bocas del Toro.

### MIocene

The early Miocene of the Garachiné region of eastern Panama has been described as follows by the geologists of the Gulf Oil Com-

pany: "Thinly bedded brown shaly material with lesser amounts of more conspicuous brown limestones. The shale is somewhat argillaceous, compacted ooze, made up largely of radiolarian remains composed of amorphous silica. Series is bituminous; seeps heavy asphaltic oil in several places. Forms small hills and ridges where exposed in tilted structure."

Oil seepages in the low swampy area bordering on the tidal flats of Garachiné Bay undoubtedly come from this shale and limestone section, though there are no exposures at the seeps. Farther inland, these rocks are known as the dry seepage horizon, from their asphalt seams. Wells of the Gulf Oil Company also encountered oil shows in this horizon. Farther east, in the Tuira-Chucunaque basin, the equivalent section is also oil-bearing and similar in lithology to that described above. It grades downward without an erosional break into the brown marl of the late Oligocene. In this area the upper part is called the Aquagua formation, the lower, the Aruza formation, and the division corresponds approximately to the terms early Miocene and late Oligocene, but no definite contact has been established.

From a well drilled by the Sinclair Panama Oil Company near the Rio Yape, a tributary of Rio Tuira, the following fauna has been determined:

<i>Agathammina</i> sp.	<i>Bulimina pyrula</i> d'Orbigny
<i>Amphistegina</i> sp.	<i>Bulimina</i> cf. <i>rostrata</i> Brady
<i>Astacolus crepidulatus</i> Montfort	<i>Bulimina sculptilis</i> Cushman
<i>Anomalina ammonoides</i> Reuss	<i>Bulimina subornata</i> Brady
<i>Anomalina arminensis</i> d'Orbigny	<i>Cassidulina crassa</i> d'Orbigny
<i>Anomalina grosserugosa</i> Gumbel	<i>Cassidulina lacrigata</i> d'Orbigny
<i>Bolivina acuariensis</i> Costa	<i>Cassidulina</i> cf. <i>subglobosa</i> Brady
<i>Bolivina argentea</i> Cushman	<i>Carulina parvensis</i> d'Orbigny
<i>Bolivina compacta</i> Sidebottom	<i>Chilostomella oroides</i> Reuss
<i>Bolivina dilatata</i> Reuss	<i>Cibicides culter</i> Parker and Jones
<i>Bolivina floridana</i> Cushman	<i>Cibicides pygmaea</i> Hantken
<i>Bolivina punctata</i> d'Orbigny	<i>Cibicides ungeriana</i> d'Orbigny
<i>Bolivina</i> cf. <i>pusilla</i> Schwager	<i>Cibicides (Truncatulina)</i> sp.
<i>Bolivina</i> cf. <i>simpsoni</i> Heron-Allen	<i>Cribrorstromoides</i> sp.
and Farland	<i>Cyclammina</i> sp.
<i>Bolivina schwageriana</i> Brady	<i>Cyclammina cancellata</i> Brady
<i>Bolivina tortuosa</i> Brady	<i>Dentalina obliqua</i> Linne
<i>Bulimina aculeata</i> d'Orbigny	<i>Ellipsoglandulina lacrigata</i>
<i>Bulimina</i> cf. <i>afinis</i> d'Orbigny	A. Silvestri
<i>Bulimina buchana</i> d'Orbigny	<i>Fissurina marginata</i> Montagu
<i>Bulimina elegans</i> d'Orbigny	<i>Fronicularia alata</i> d'Orbigny
<i>Bulimina elongata</i> d'Orbigny	<i>Gaudryina lacrigata</i> Franke
<i>Bulimina inflata</i> Seguenza	<i>Gaudryina paupercula</i> Cushman
<i>Bulimina marginata</i> d'Orbigny	<i>Gaudryina rotunda</i> Reuss
<i>Bulimina pupoides</i> d'Orbigny	<i>Gaudryina subrotundata</i> Schwager





<i>Glandulina laevigata</i> d'Orbigny	<i>Patrocles rotulata</i> (Lamarck)
<i>Glandulina rotundata</i> Reuss	<i>Patrocles submamilligera</i>
<i>Globigerina bulloides</i> d'Orbigny	(Cushman)
<i>Globigerina cretacea</i> d'Orbigny	<i>Patrocles vauhani</i> (Cushman)
<i>Globigerina conglobata</i> , Brady	<i>Planulina ariminensis</i> d'Orbigny
<i>Globigerina dubia</i> Egger	<i>Plectrofrondicularia</i> sp. (bicostate)
<i>Globigerina</i> cf. <i>trilobata</i> Costa	<i>Plectrofrondicularia</i> sp. (tricostate)
<i>Gyroidina soldanii</i> d'Orbigny	<i>Plectrofrondicularia</i> sp. (quadrate)
<i>Haplophragmoides</i> sp.	<i>Polymorphina gibba</i> d'Orbigny
<i>Haplophragmoides canariensis</i>	<i>Polymorphina burdigalensis</i>
d'Orbigny	d'Orbigny
<i>Lagena</i> sp.	<i>Pullenia sphaeroides</i> d'Orbigny
<i>Massilina</i> sp.	<i>Rheofax</i> (?)
<i>Mucronina</i> ( <i>heracostata</i> ) d'Orbigny	<i>Reussella</i> (?)
<i>Nodosaria costulata</i> Reuss	<i>Rosalina</i> ( <i>Discorbina</i> ) <i>globularis</i>
<i>Nodosaria consobrina</i> d'Orbigny	(d'Orbigny)
<i>Nodosaria</i> cf. <i>farcimen</i> Reuss	<i>Rotalia beccarii</i> Linne
<i>Nodosaria filiformis</i> d'Orbigny	<i>Rotalia globularis</i> (d'Orbigny)
<i>Nodosaria hispidula</i> d'Orbigny	<i>Sigmöilina</i> sp.
<i>Nodosaria obliqua</i> Linne	<i>Siphogenerina</i> sp.
<i>Nodosaria</i> cf. <i>pyrula</i> d'Orbigny	<i>Siphonina reticulata</i> Czjzek
<i>Nodosaria radricula</i> (Linne)	<i>Sphaeroidina bulloides</i> d'Orbigny
<i>Nodosaria sagrinensis</i> Bagg	<i>Spiroloculina</i> sp.
<i>Nodosaria soluta</i> Reuss	<i>Tertularia abbreviata</i> d'Orbigny
<i>Nodosaria vertebralis</i> (Batsch)	<i>Tertularia agglutinans</i> d'Orbigny
<i>Nonion boucanus</i> d'Orbigny	<i>Tertularia gramen</i> d'Orbigny
<i>Nonion pompilioides</i> Fichtel and	<i>Tertularia sagittula</i> DeFrance
Moll	<i>Themcon</i> ( <i>Polystomella</i> ) <i>sagra</i>
<i>Nonion scapha</i> Fichtel and Moll	d'Orbigny
<i>Nonion umbilicatulula</i> Walker and	<i>Trigonulina obliqua</i> Seguenza
Jacob	<i>Triloculina</i> sp.
<i>Orbulina universa</i> d'Orbigny	<i>Uvigerina asperula</i> Chapman
<i>Patrocles calcar</i> (Linne)	<i>Uvigerina canariensis</i> d'Orbigny
<i>Patrocles</i> ( <i>Cristellaria</i> ) sp.	<i>Uvigerina pygmaea</i> d'Orbigny
<i>Patrocles cultrata</i> (Montfort)	<i>Uvigerina</i> cf. <i>tenuistriata</i> Reuss
<i>Patrocles mamilligera</i> (Karrer)	<i>Virgulina squamosa</i> d'Orbigny
<i>Patrocles reniformis</i> (d'Orbigny)	<i>Verneuilina</i> cf. <i>pygmaea</i> Egger

The Aquagua formation is bentonitic in some parts of the section, and in the Yape well, bentonite beds were conspicuous aquifers. It is believed that the forms listed above are entirely from the early Miocene. The Aquagua formation has been mapped as far north as the Membrillo River, in the central Chucunaque valley, but the outcrop grows smaller from the Tuira northward, apparently partly because of progressive overlap of the middle Miocene, and perhaps to erosion at the mid-Miocene uplift; but seven or eight miles west on the Rio Sabana it is present apparently to a thickness of 2,000 feet or more. On the Pacific coast south of Garachiné Point, a nar-

row band of it appears standing on edge or dipping steeply in contact with the basement rocks.

In central Panama the early Miocene has been carefully studied only in the Canal Zone, where it is recognized by Woodring and Thompson (1949) only in the region south of Gamboa, and in the Madden Lake basin. In the Gaillard cut it is represented by the Cucaracha formation which is mostly nonmarine, consisting of carbonaceous and lignitic shale, and massive greenish gray bentonitic and tuffaceous clayey sandstone. There is usually a conglomerate at the base. The bulk of the formation is the bentonitic clay.

The La Boca formation, known mostly from borings, according to Woodring and Thompson, extends from the Gaillard cut to the Pacific entrance of the Canal, and is chiefly silty or sandy mudstone. Conglomerate and sandstone are found in some bore holes in the lower part. Near the base cream-colored coralliferous limestone of the type of the Emperador interfinger with the clays of the Cucaracha formation. In the Pedro Miguel area the Pedro Miguel agglomerate overlies the Cucaracha, but the lower part of it is apparently equivalent to the upper part of the thicker Cucaracha section.

The Panama tuff is apparently a facies of the Cucaracha, a well-stratified water-laid rhyolitic tuff with fragments of punice. A few foraminifera of Oligocene age have been found in the type region near Diablo Heights, but these are probably inherited.

In the Madden Lake basin, the youngest rocks exposed are massive, fossiliferous tuffaceous sandstones, which form the foundation of Madden dam. Olsson (1942) named the formation the Alhajuela sandstone. These sandstones are increasingly calcareous downward and have been divided by Woodring and Thompson (1949) into the upper Alhajuela sandstone member and the calcareous sandstone member. The latter contains so much lime that it might in some places equally well be called a sandy limestone. The caves caused by solution in this member were a serious engineering obstacle in the construction of the Madden Dam, as some of them were of dimensions ranging up to 100 feet. This member, according to Woodring and Thompson, carries *Turritella gatlensis*, and is assigned to the early Miocene. The Chilibrillo limestone which underlies it may be the equivalent of the Emperador of the Canal Zone. It is considered to be early Miocene by Woodring and Thompson. In the region between Gamboa and the limits of the Canal Zone west of Gatun Lake, early Miocene rocks are missing, according to Woodring and Thompson (1949), but Jones (1950) disagrees.

West of the Canal Zone in central Panama, the early Miocene is

probably represented only by volcanic ejecta, but lack of fossiliferous sediments makes any dating questionable. Basic lavas and agglomerates form the surface from the Canal westward to Capira, beyond which acidic rocks are found. The quartz sand beaches below these acid rocks have been a much sought source of sand for concrete work around Panama City. In the south wall of El Valle crater, well-bedded rhyolitic tuffs, much resembling the Panama tuffs at Diablo Heights, dip southward, and similar material with crossbedded tuffaceous clays, sands, and gravels occurs in the vicinity of Penonomé. Some of the sediments are diatomaceous, but no marine fossils were seen. They are believed to be fresh-water deposits. Similar material occurs along the road to La Pintada, a town about two miles south of the continental divide and seven miles north of Penonomé. About a mile north of La Pintada basic lavas appear, which are believed to belong to the basement complex, as between these andesites and La Pintada is a chert outcrop, a rock which is known elsewhere in Panama only from below the late Eocene at the top of the basement complex. To the south and east of La Pintada on the trail to El Valle are outcrops of rhyolite resembling the north wall of the El Valle crater. The rhyolite flows also occur along the road from Penonomé to Natá, where they can be traced westward to the Rio Grande where andesite flows begin. The andesite flows strike northeast and dip northwest, but the rhyolite flows and ash strike east-west and dip south, apparently overlapping the andesite. The andesite flows form the foothills of the continental divide toward which they dip. They can be traced westward to the vicinity of Cañazas where they are overlain by shale of probable early Miocene age, and on north to the continental divide.

The structure is well shown in Hershey's (1901) structure section. (II-II). The writer has made many plane flights along this mountain front and has checked the northward dip of the lavas and interbedded sediments. It would appear that the andesite flows can not be younger than early Miocene nor older than late Oligocene, and that they were eroded and overlain by the rhyolite in the Natá-Penonomé-La Pintada area. Shales of the Santiago formation of Hershey are considered to be of early Miocene age by Woodring and late Oligocene by Olsson (1942) The lava beds to the north overlie them and are without much doubt early Miocene.

Collections made by Sinclair geologists in the vicinity of Santiago are deposited in the United States National Museum, but have not been studied. The collector's notes are of some interest:

On the road from Santa Maria to Santiago—2nd hill of main divide 5



miles northeast of Santiago—close-textured shaly ls.—*Melanopsis*, *Cyrcanacea* (?) like *Inoceramus*, fresh-water fauna. (U.S.N.M. Coll. 8465.)

Three-quarter mile southwest of Santiago on road to Montijo—calcareous agglomeratic ss. Large *Amusium*, *Ostrea*—small, falcate, narrow sharp plication of entire periphery, *Phacoides*, *Chione*, *Arca* (*Cunearca*), *Harpa*, large *spatangoid echinoid*. (U.S.N.M. Coll. 8466.)

Road crossing of Río Martin Grande, one-quarter mile west of Santiago—agglomeratic ss. *Turritella* cf. *venezuelana*, *Oliva*, *Terebra*, with large axial costae on anterior half of whorl, 2 spiral bands on posterior half, *Conus*, *Triton*, *Natica* small, *Nassa*, *Glycymeris*, *Phacoides* cf. *anodonta*, *Venericardia*, *Pitaria*, fragments of *Crassatella* cf. *berryi*. (U.S.N.M. Coll. 8467.)

These last beds appear to Olsson (personal communication) to be borderline late Oligocene or early Miocene.

In Bocas del Toro Province, early Miocene shales form the upper part of the Uscari formation and have been described by Olsson (1922), who lists a molluscan fauna. Many of the foraminifera previously listed under the late Oligocene of Bocas-del Toro also occur in the early Miocene, but only three—*Eponides parantillarum*, *Discorbis berthelotti*, and *Spiroloculina alveata* are apparently limited to the Miocene in the recovery from the Bocas well.

South of the divide in Chiriquí Province, the early Miocene consists of tuffaceous shales and shaly sandstones. From collections in the United States National Museum, Olsson has identified the following (personal communication):

*Arca macdonaldi* Dall

*Arca vetchi* Olsson

*Architectonica sexlinearia* Nelson

*Chione propinqua* Spieker

*Clementia dariena* Conrad

*Conus multiliratus* Bose

*Crassatella berryi* Spieker

*Dosinia* cf. *delicatissima*

Brown and Pilsbry

*Mastra* cf. *pleatella* Lamarck

*Phos inornatus* Gabb

*Turritella altilira* Conrad

*Turritella* cf. *venezuelana* Hodson

A well drilled a few miles north of David is stated to have passed directly from middle Miocene to Oligocene with no early Miocene present. It is possible that this may be because of erosion preceding the Gatun deposition, or the statement may be merely the paleontologist's opinion regarding the disputed position of the Oligocene-Miocene contact.

On the Burica Peninsula, lower Miocene is possibly present. From a collection on the upper San Bartolo River, *Nonion grateloupi*, *N. mesonense*, *Quinqueloculina lamarckina*, and *Virgulina pontoni* have been identified by Clift.

In general the early Miocene of eastern Panama is an offshore deposit of fine texture with some fine volcanic matter; in central Panama, it is shallow water or terrestrial with large amounts of volcanic ejecta of all sorts, agglomerates, flows, tuffs, and ash; in western Panama, it is a fine-textured shale of offshore type in Bocas del Toro, somewhat sandier in Chiriquí and Costa Rica, and becomes conglomeratic in central Costa Rica west of Puerto Limón. The difficulty in distinguishing the early Miocene from late Oligocene appears to be about the same everywhere, indicating continuity of deposition in all areas without regard to the character of the deposit.

### MIDDLE MIOCENE

The long period of continuous deposition from late Eocene through early Miocene was broken in mid-Miocene time by uplift and erosion in all parts of the Isthmian region. The uplift was accompanied by vulcanism in western and central Panama, but apparently not in eastern Panama. Folding and faulting were a part of the movement, but much of the evidence is concealed beneath the deposits of middle Miocene and later time. The angular unconformity between middle Miocene and older sediments is sharply marked in the Burica Peninsula, where on the upper Rio La Vaca, Eocene limestone striking N. 55° W. and dipping 65° NE. is overlain by Miocene conglomerate and sandstone striking N. 75° W. and dipping 43° NE., and not far away the Miocene with about the same dip and strike lies on the edges of vertical Eocene limestone beds striking N. 72° W. Angular unconformity between early and middle Miocene is generally much less sharp, although often perceptible. As there has been much post-Miocene folding, followed by erosion, the middle Miocene is now found mostly in synclines, grabens, and basin areas, and is generally lacking on anticlinals, horsts, or other areas of uplift.

The best-known middle Miocene is in the sedimentary basin centered round Gatun at the northern end of the Panama Canal. This region because of its accessibility and economic and strategic importance has long been the object of study, and as it has not been much affected by post-Miocene tectonic movements, the sequence, thickness, and character of the beds has been well established. The basin is gently arcuate, opening to the northwest and the strike of the basal contact varies from nearly due north-south on the east side of the basin to about N. 70° W. at the west side. On the east side, the Gatun rests on the basement rocks, but on the southeast, south, and southwest sides it lies on the late Oligocene (lower Caimito), or early Miocene, according to Jones (1950).

Jones describes the Gatun as "mudstones, siltstones, conglomerates and tuffs, all thickly and massively bedded. The siltstones, sandstones, and conglomerates are variably marly and tuffaceous, highly fossiliferous and massively jointed. . . . The tuffs are uniformly grained siltstones and claystones except for local streaks, sparsely scattered with pumice pebbles and cobbles. The formation has a thickness known to exceed 1,400 feet and probably much more."

Olsson (1942) divides the Gatun into three parts, a lower and upper member of marine, highly fossiliferous sandstones, shales, and argillaceous limestones; the middle member tuffaceous sandstones, or beds of fuller's earth with plant remains, only rarely containing marine fossils. He cites the principal fossils of the base as *Pecten gatunensis* Toula, *Arca dariensis* Brown and Pilsbry, *Clementia dariena* Conrad, *Antigona caribbeana* Anderson, *Conus molus* Brown and Pilsbry, *Turritella gatunensis* Conrad. At the Gatun spillway, he finds underneath this a brown, gray, or black tuffaceous sandstone, with lignitic material and plant remains, and carrying a few marine fossils, such as *Bittium*, *Cerithium*, *Conus*, *Arca*, *Tellina*, and *Nucula*. This series he assigns to the Caimito. Keen and Thompson (1946) and Woodring and Thompson (1949), however, include it and other still lower beds in the Gatun.

Keen and Thompson (1946) list from the lowest exposed Gatun, "a subgenus, *Bornia* (*Temblornia*), known elsewhere only in the Round Mountain silt (Temblor) of California. *Cancellaria* (*Aphera*) *islacononis* Maury, the zone fossil of the Cercado formation of Hispaniola, occurs somewhat higher, in the middle part of the lower Gatun. Therefore, the lower part of the Gatun may be in part older than middle Miocene."

In eastern Panama, two outcrops of middle Miocene have been mapped, a small area in the Sambú basin south and east of Garachiné, and a much larger area in the Tuira-Chucunaque basin in eastern Darien. In the Tuira basin the middle Miocene is in general divisible into three parts, a lower member of conglomerate and sandstone with small limestone lenses, a middle member of shale and shaly sandstone, and an upper member of limey sandstone with limestone in thin beds or lenses. The upper member is the most fossiliferous and carries a fauna closely related to that of the Mount Hope section of the Canal Zone Gatun. The sandstone and limestone of this member stand up strongly against erosion, form ridges or cliffs along rivers so that its outcrop is easily followed. Its distinctive appearance has led to its being given member status under the name Pucro, the other two members being grouped as lower Gatun. The fossils collected by the Sin-

clair party of 1923-24 have not been carefully studied, but among the commoner forms in the Puero are:

*Arca chiriquiensis* Gabb  
*Cancellaria dariena* Toulà  
*Cancellaria solida* Sowerby  
*Fasciolaria gorgosiana*  
Brown and Pilsbry  
*Malca camura* Guppy

*Melongenella consors* Sowerby  
*Murex messorius* Sowerby  
*Panopea reflexa* Say  
*Pitarina gatunensis* Dall  
*Turritella robusta* Grzybowski

The conglomerate at the base of the lower Gatun has a thickness of about 300 feet near the Colombia border, but increases northward reaching a maximum of about 1,900 feet on the Rio Chico, the southernmost tributary of the Chucunaque. There the conglomerate is extremely heavy at the base, containing boulders up to six feet in diameter and thins out rapidly in all directions. It apparently is a delta deposit and probably indicates the position of the mouth of a large and vigorous river of middle Miocene times. The lower Gatun sandstone, while richly fossiliferous is perhaps less so than the Puero. Heavy-shelled mollusks are plentiful in the lower member, with foraminifera and thin-shelled mollusks in the shale above. Leaves and bits of wood or charcoal are common in the shale, which in many places has a greenish cast. In spite of the presence of much vegetable matter, the Darien Gatun is not lignitic like that of Chiriquí and Bocas del Toro. Attempts to measure the thickness of the middle Miocene of the Chucunaque-Tuira basin have encountered the usual difficulties, massive bedding in the sandstones, discontinuous outcrops in the shales, and numerous faults, which are difficult to evaluate and often are passed unseen by geologists who confine their observations to the rivers. A probable maximum thickness for the lower Gatun is 3,300 to 3,500 feet, and for the Puero 1,500 to 2,000 feet, but the average amounts for each member would be somewhat less.

The middle Miocene represents transgressive overlap in the two lower members and off lap in the Puero, continued in the overlying Chucunaque formation of late Miocene and perhaps Pliocene age. In the Sambú basin, the middle Miocene is less well known. Its thickness is estimated at 2,700 feet with a sandy conglomeratic limestone at the top, composed largely of oyster and pecten shells, probably corresponding to the Puero and shales and sandstones below. There is no evidence that the two areas, Sambú and Tuira, were ever in communication with each other. There was no vulcanism in these areas in mid-Miocene time.

In western Panama, the deposition of the middle Miocene was preceded and accompanied by widespread vulcanism, which has left

a record in the form of dikes, flows, and plugs, as well as much tuffaceous matter included in the sediments. In addition to the marine beds, terrestrial deposits including a considerable amount of low-grade coal and lignite occur in Bocas del Toro and the Caribbean side of Costa Rica, and to a lesser extent in the foothills of the cordillera in Chiriquí and on Isla Muertos off the Pacific coast. In Bocas del Toro the coal beds are found in several of the islands off the coast, in the Valiente Peninsula, and in the headwaters of the Changuinola River, and continue in the hills on the inner side of the coastal plain in Costa Rica. They apparently lie in the upper part of the formation and may not be represented by contemporaneous marine deposits except offshore.

The middle Miocene in western Panama has not been studied as closely as in central and eastern Panama, and is less well known. The formation in general carries a fauna closely related to that of Gatun. The mollusks have been described by Olsson (1922). Coarse conglomerates occur, not only at the base, but throughout the formation, even at the top, where they are transitional with the Pliocene conglomerate; shales are present but not so plentifully as in other parts of the country. Sandy lenticular limestones are common, and in the coastal belt coral reef limestones, usually of small dimensions, occur. The larger part of the formation is coarse gray tuffaceous sandstone derived mainly from the volcanics of the basement complex and the andesite flows which form the base of the Gatun in many places. Black sand beaches, composed largely of magnetite, occur in some places where the Gatun is furnishing most of the sediment brought down by the rivers. On Isla Colon (Columbus Island) and Isla Bastimentos (Provision Island) the base of the Gatun is a shale (Bastimentos shale) which interfingers with a coralline limestone (Minitimi limestone). No conglomerate is present, but there is probably an erosion interval at the base of Minitimi-Bastimentos formation. The underlying Coneh Point shale (lower Miocene) resembles the Bastimentos shale so closely that field geologists have had great difficulty in separating them. Both are massive, poorly bedded, soft, gray clay shales, which weather so rapidly that fresh exposures are rare. On some of the other islands and on the Valiente Peninsula at the eastern end of Chiriquí Lagoon, the base of the Gatun is basaltic or andesitic flows.

The middle Miocene of Chiriquí is mostly concealed by younger rocks, principally by the volcanic ejecta of El Barú. An area west of David shows about 500 feet of section mostly sandstone, but because of low dips, and massive bedding, and a great deal of faulting, the

actual thickness present is only approximately known. Cross-bedded, poorly consolidated sandstones, and soft sandy shales carrying a considerable amount of vegetable remains, make up the visible part of the section. Fossils collected from the area have not been carefully studied, but field workers have agreed that they are closely related to those of the Canal Zone Gatun. On the Burica Peninsula, the Miocene is transitional with the Pliocene, and over a range of some 3,500 feet of section, foraminifera, which in the United States are considered diagnostic for each of the two periods, are intermingled. This condition apparently includes both late and middle Miocene, and the resulting confusion will probably not be disentangled for many years to come. A fauna collected from various stations in Rio San Bartolo, near Puerto Armuelles, and determined by W. O. Cift, is appended:

*Bolivina* sp.

*Bolivina* cf. *acerosa* Cushman

*Bolivina* cf. *alazanensis* Cushman

*Bolivina interjuncta* var. *bicostata*

*Bolivina malkiniae*

Coryell and Embich

*Bolivina marginata* Cushman

*Bulimina inflata* Seguenza

*Bulimina pupoides* d'Orbigny

*Buliminella elegantissima*

(d'Orbigny)

*Candorbulina univerrsa* Jedlitschka

*Cassidulina californica*

Cushman and Hughes

*Cassidulina* cf. *crassa* d'Orbigny

*Cibicides isidroensis*

Cushman and Renz

*Cibicides refulgens*

Denys de Montfort

*Cibicides sinistratus*

Coryell and Rivero

*Cibicides* sp.

*Eponides coryelli* Palmer

*Gaudryina soldanensis*

Cushman and Renz

*Globigerina bulloides* d'Orbigny

*Globigerina concinna* Reuss

*Globigerina triloba* Reuss

*Globigerina* sp.

*Globorotalia menardii* (d'Orbigny)

*Gyroidina soldanu* d'Orbigny

*Marginulina pediformis* Bornemann

*Nonion grateloupi* (d'Orbigny)

*Nonion mesonense* Cole

*Nonionella auris* (d'Orbigny)

*Nonionella miocenica* Cushman

*Nonionella miocenica* var. *stella*

Cushman

*Planulina ariminensis* d'Orbigny

*Pyrgo* sp.

*Quinqueloculina lamarckiana*

d'Orbigny

*Quinqueloculina seminula* Reuss

*Rotalia caloosahatcheensis* Cole

*Robulus oblongus*

Corvell and Rivero

*Saracenaria acutauricularis*

Fichtell and Moll

*Textularia* sp.

*Trochammia* sp.

*Urigerina beccarii* Fornasini

*Urigerina pygmaea* d'Orbigny

*Valvulina oviedoiana* d'Orbigny

*Virgulina pontoni* Cushman

*Virgulina* sp.

The stream crosses outcrops of various formations from Eocene to Pliocene, as can be seen from the map.

## UPPER MIOCENE AND PLIOCENE

As noted in the preceding paragraphs, the late Miocene and Pliocene of western Panama can not at present be distinguished by the fossils, owing to the overlap of diagnostic species. A fauna collected by the writer was determined by Coryell and Mossman (1942) as Pliocene. Other paleontologists, however, regard it as late Miocene, and a similar condition exists with regard to the Toro and Chagres formations of the Canal Zone and the Chucunaque formation of Darien. In all three cases, the formations in question overlie middle Miocene beds conformably, and with no evidence of a persistent erosion interval, although there may be small local breaks. The Chagres formation has been described by Jones (1950) and by Woodring and Thompson (1949). It is a shallow-water marine sandstone of which a limy phase is given member rank under the name Toro. It is limited to a zone 7 to 10 miles in width along the coast west of the Caribbean entrance to the Canal Zone. It narrows westward and apparently disappears at some point within the next 15 miles. According to the mapping by Jones, it overlaps the Gatun increasingly westward.

In the Tuira-Chucunaque basin in eastern Panama, the youngest consolidated sediments are a series of sandstones and shales carrying a marine fauna, mainly foraminiferal. It has been correlated with the Chareo Azul of Coryell and Mossman (1942) and is thus involved in the same age controversy. It overlies the Puero sandstone of upper middle Miocene age apparently conformably, beginning with a massive cross-bedded sandstone followed by gray foraminiferal shales, and at the top is again sandy. It occupies the trough of the long narrow synclinerium stretching from Chepo to and beyond the Colombian border, and in central Darien occupies a low swampy area, much of which has been peneplaned or baseleveled. Where outcrops occur, the formation is seen to have been deformed by folding and faulting, apparently prior to the peneplanation. No material of fresh volcanic origin has been noted. An interesting feature is a narrow band of flat chert pebbles near the base. Since chert is known to occur only below the Eocene at the base of the sedimentary column, it would seem that this occurrence represents erosion of a chert horizon at some point within the "forbidden land" of the Cuna Indian reservation, as chert is not known south of Membrillo. The Chucunaque is a normal marine off-lap deposit, and represents the final withdrawal of the sea from this part of the Isthmian region. It should be noted that the formation is not known in Darien outside the Chucunaque basin, but that its greatest width is at the south end of the basin, suggesting that it,

like the conformably underlying Pucro, once extended to and beyond the Colombian border. However, the paleontological correlation with the Charco Azul suggests that the final connection of this arm of the sea may have been with the Pacific rather than the Caribbean. If this arm of the sea were simply cut off and left to dry up, salt and gypsum deposits would be expected, but have not been reported, nor is the fauna depauperate, so far as known.

In Bocas del Toro and adjacent Costa Rica, upper Miocene has not been differentiated, but it may well be present. On the Pacific side of western Panama, the Charco Azul formation, considered to be Pliocene by Olsson (1942) and by Coryell and Mossman (1942) apparently includes as much or more Miocene than Pliocene. A. D. Brixey, Jr., in a report on foraminifera from a well drilled near Puerto Armuelles makes the following comment:

From the surface down to 1900 feet the foraminifera show closer affinities with Pliocene age (Charco Azul) than to Pleistocene species of the Armuelles formation. The marked absence of *Miliolidae* and *Textularidae* from 10 to 100 feet especially would tend to support a Pliocene (Charco Azul) age for the upper part of the Corotú well. The presence of rather abundant *Valvulinaria inflata*, *Bolivina costata* var. *bicostata*, *Bulminella constans* cf. var. *basispinata*, and *Bulimina denudata* also substantiate this belief.

Due to the overlapping range of certain foraminifera species, the contact between the Miocene and Pliocene can not be sharply defined, either by changes in lithology or by the distribution of foraminifera. In addition to the species mentioned above which are Charco Azul types, other species were found which point to Pliocene strata down to at least 1900 feet. At 1900 feet, a well-preserved large *Robulus americanus* var. *grandis* showed strong resemblance to *R. americanus* cf. var. *grandis* which occurs in the Bowden formation of Jamaica. This occurrence is especially interesting because *R. americanus* cf. *grandis* was the only species more typical of the Atlantic-Caribbean middle Tertiary faunal zone, the other species being more characteristic of the Pacific coast middle Tertiary. One from the upper Monterey shale of California (*Nonionella* cf. *miocenica*), was found at 1484 and 1720-1750 feet. Since only two specimens of *N. miocenica* were found, there are two explanations for the occurrence: (a) either the form was in a section of reworked sediments, or (b) the range of this species is greater than originally believed. It is significant, however, that *N. miocenica* was the only typical Miocene species occurring between 1485 and 1750 feet. One of the shortcomings in using foraminifera for correlation studies is that quite often they appear as reworked specimens, having been moved by currents and/or waves from different ecological zones or from different horizons.

A Mio-Pliocene age is given the section between 1900 and 5400 feet, due to the presence of foraminifera which were characteristic of both Pliocene and Miocene age sediments. Three species believed by Kew to be characteristic of the lower Pico formation, lower Pliocene, of California were found in the section between 5290 and 5300 feet. These species were *Gyroldina soldani* var. *rotundimargo*, *Bulimina pagoda* var. *hebespinata* and *Virgulina* cf. *no-*



*dosa*. In the same section the following Miocene forms were identified: *Nodogenerina advena* and *Baggina* cf. *cancriformis*, *Nodogenerina advena*, first recognized in the lower Mohnian, Luisian, Relizian, and Saucesian of California, would indicate an upper middle to lower middle Miocene age. *Baggina cancriformis* is typical of the lower Monterey (lower Relizian and lower Modelo shale of Las Sauces Creek) of California.

Definite Miocene species begin at about 5400 feet and continue to 7790 feet where the last microfossils were encountered. These species include the following: *Bolivina aenariensis* (which first appeared in the Mio-Pliocene at 4540 feet), *Cassidulina margureta*, two additional occurrences of *Nodogenerina advena*, *Uvigerinella* cf. *californica*, *U. obesa* and *Virgulina floridana*. The last foraminifera identified in Corotú No. 1 were a broken *Bathysiphon* sp. and a poorly preserved *Bolivina* sp. which were both found at 7770 feet. (Private report by A. D. Brixey, Jr., to Sinclair Panama Oil Co., 1949.)

The fauna as determined by Brixey is as follows:

	Depth in Feet		
	<i>Plio</i>	<i>Mio-Plio</i>	<i>Mio.</i>
<i>Angulogerina angulosa</i> Williamson	180- 190		
<i>Angulogerina carinata</i> Cushman	110- 150		
<i>Angulogerina occidentalis</i> Cushman			6050-6060
<i>Anomalina grosserugosa</i> Gumbel	180-1120		
<i>Anomalina</i> sp. ....			
<i>Baggina cancriformis</i> Kleinpell			5410-5420
<i>Bolivina advena</i> Cushman ..			5410 5420
<i>Bolivina aenariensis</i> (Costa)		4540 1550	5420-5440
<i>Bolivina alata</i> (Seguenza) . .	1435-1860	2400-2410	
<i>Bolivina costata</i> var. <i>bicostata</i> d'Orbigny	0-1750	3220-5300	
<i>Bolivina dattiana</i> Coryell and Mossman ..	110 - 190		
<i>Bolivina foraminata</i> Stewart		2000 5300	
<i>Bolivina floridana</i> Cushman ..			5410- 5475
<i>Bolivina interjuncta</i> Cushman	0 1900	4780	5440
<i>Bolivina marginata</i> Cushman			5410-5440
<i>Bolivina</i> cf. <i>pomposa</i> Coryell and Mossman ..	0- 120		
<i>Bolivina</i> cf. <i>punctata</i> d'Orbigny			6340-6400
<i>Bolivina</i> cf. <i>simplex</i> Phleger and Parker ..			6730-6790
<i>Bolivina sinuata</i> var. "B" Galloway and Wissler .		4790-5300	
<i>Bolivina subadvena</i> var. <i>spissa</i> Cushman ..	1435-1750		
<i>Bolivina</i> sp. ....			6850-7770
<i>Bulimina affinis</i> d'Orbigny	0- 10		
<i>Bulimina</i> cf. <i>denudata</i> Cushman and Parker ...	1235-1900	4010-5300	
<i>Bulimina elongata</i> d'Orbigny			5430-5440

	Depth in Feet		
	<i>Plio.</i>	<i>Mio- Plio.</i>	<i>Mio.</i>
<i>Bulimina inflata</i> Seguenza .....			6250-6260
<i>Bulimina marginata</i> d'Orbigny .....	110- 190		
<i>Bulimina</i> cf. <i>pupoides</i> d'Orbigny .....	1235-1750	4540-4560	
<i>Bulimina pagoda</i> Cushman .....	0-1660	3000-5000	
<i>Bulimina pagoda</i> cf. var. <i>hebespinata</i> R. E. and K. C. Stewart .....		5290-5300	
<i>Buliminella curta</i> Cushman .....	190		5420
<i>Buliminella curta</i> var. <i>basispinata</i> Stewart .....	140- 190		
<i>Cancris</i> cf. <i>panamensis</i> Natland .....	1406-1416		
<i>Cassidulina californica</i> Cushman and Hughes .....	0	5000	
<i>Cassidulina</i> cf. <i>cushmani</i> R. E. and K. C. Stewart .....	120		
<i>Cassidulina margareta</i> Karrer .....			5700-6390
<i>Cassidulina</i> cf. <i>pulchella</i> d'Orbigny .....	140	5300	
<i>Chilostomella czjzeki</i> Reuss .....	0- 190		
<i>Chilostomella</i> cf. <i>ovoides</i> Reuss .....	1720-1750		
<i>Cibicides americanus</i> (Cushman) .....	1236	5300	
<i>Cibicides</i> cf. <i>hodgeri</i> Cushman and Schenck .....			5410 5420
<i>Cyclammina cancellata</i> Brady .....		4190-4200	
<i>Dentalina</i> cf. <i>soluta</i> Reuss .....	1090-1100		
<i>Ellipsolagena</i> sp. ....			5410-5420
<i>Epistomina bradyi</i> Galloway and Wissler .....	0		5300
<i>Globigerina bulloides</i> d'Orbigny .....	0		7780
<i>Globigerina conglomerata</i> Schwager .....			6000-6350
<i>Globigerinoides</i> cf. <i>sacculiferus</i> Brady .....	110- 120		
<i>Globigerinoides triloba</i> Reuss .....	1110	5300	
<i>Globorotalia menardii</i> d'Orbigny .....	0		5400
<i>Guttulina</i> sp. ....			6050-6060
<i>Gyroidena soldanii</i> d'Orbigny .....	0		5420
<i>Gyroidena soldanii</i> var. <i>rotundimargo</i> .....		5290-5300	5290
<i>Haplophragmoides</i> sp. ....			5430-5440
<i>Lagena</i> cf. <i>sulcata</i> Walker and Jacob .....	1306- 201	2010	
<i>Lagena</i> sp. "A" .....	0- 10		
<i>Lagena</i> sp. "B" .....		4990-5000	
<i>Nodogenerina advena</i> Cushman and Laiming .....		5290	6350
<i>Nodogenerina</i> sp. ....			5410-5420
<i>Nodosaria</i> sp. ....		4190	5460
<i>Nonion costifera</i> Cushman .....	1500		
<i>Nonion incisum</i> Cushman .....	180	5300	
<i>Nonion scapha</i> Fichtel and Moll .....	1236	3230	
<i>Nonionella</i> cf. <i>miocenica</i> Cushman .....	1485-1750		
<i>Orbulina universa</i> d'Orbigny .....	0		5430
<i>Planulina arimincensis</i> d'Orbigny .....		3000-4200	

	Depth in Feet		
	Plio.	Mio-Plio.	Mio.
<i>Plectofrondicularia californica</i>			
Cushman and Stewart .....		4540	7730
<i>Pleurostomella</i> sp. ....			6850-6860
<i>Polystomella crispa</i> Linne .....	0- 10		
<i>Pyrgo</i> cf. <i>depressa</i> d'Orbigny .....	0- 190		
<i>Quinqueloculina akneriana</i> d'Orbigny .....	0-1416		
<i>Quinqueloculina oblonga</i> Montagu .....	1650-1660		
<i>Quinqueloculina seminuda</i> Reuss .....	1720		
<i>Quinqueloculina</i> sp. ....	110	5300	
<i>Robulus americanus</i> var. <i>grandis</i>			
Cushman .....		1900-1910	
<i>Robulus</i> cf. <i>calcar</i> Linne ..			6340-6350
<i>Robulus cushmani</i> Galloway and Wissler ..	0	3000-3010	
<i>Robulus</i> cf. <i>simplex</i> d'Orbigny .....			6050-6060
<i>Robulus</i> sp. ....		5290	5420
<i>Rotalia subtenera</i>			
Galloway and Wissler ..	110- 120		
<i>Sigmolima tenuis</i> Czjzek .....		4010-4020	
<i>Textularia abbreviata</i> d'Orbigny .....		2000-3010	
<i>Textularia</i> sp. ....			5410-5420
<i>Uvigerina brunnensis</i> Karrer ..	10- 120		
<i>Uvigerina</i> cf. <i>hispida-costata</i> ..		3000-3010	
<i>Uvigerina</i> cf. <i>mexicana</i> Nuttall ..			5410-5420
<i>Uvigerina peregrina</i> Cushman ..	0- 10		
<i>Uvigerina striata</i> Schwager ..	110	5300	
<i>Uvigerina striata</i> cf. <i>attenuata</i>			
Coryell and Mossman .....	0	5000	
<i>Uvigerina</i> cf. <i>tenuistriata</i> Reuss ..		5420-5430	
<i>Uvigerinella</i> cf. <i>californica</i> Cushman .....			6340-6350
<i>Uvigerinella obesa</i> Cushman ..			6000-6060
<i>Valvulineria inflata</i> d'Orbigny ..	0-1416		
<i>Valvulineria</i> sp. (large) ..	180- 190		
<i>Valvulineria</i> sp. (small) ..			7090-7100
<i>Virgulina bramlettei</i>			
Galloway and Morrey ..			6050- 6060
<i>Virgulina</i> cf. <i>californiensis</i> Cushman ..			7720-7730
<i>Virgulina floridana</i> Cushman ..			6850-6860
<i>Virgulina</i> cf. <i>nodosa</i>			
R. E. and K. C. Stewart ..		5290-5300	
<i>Virgulina</i> sp. ....			6340 6350

The Charco Azul is predominantly shale and siltstone, carrying plant remains and lignitic seams as well as an abundant marine fauna of mollusks and foraminifera. The mollusks have been described by Olsson (1942) and the foraminifera by Coryell and Mossman (1942). Occasional beds are sandy or limy, but there is little true sandstone or limestone. The base is conglomeratic, and at the eastern side of

the Burica Peninsula (near Puerto Armuelles) in Rio Corotú the basal conglomerate runs to 600 feet in thickness, the boulders of the conglomerate being almost entirely of basic igneous rocks. The conglomerate thins westward and is thinnest where it lies on the basal complex near the west side of the peninsula.

The Chareo Azul is a strongly transgressive formation, its base lying on successively older formations from northeast to southwest, and represents an advance of the sea toward the southwest on a land body of unknown size, which was certainly a large island and may have been of subcontinental dimensions, since the western limit of continental structure in the eastern Pacific is a line running from a point west of Easter Island to southern Mexico (Gutenberg and Richter (1949), p. 27). The Chareo Azul has never been identified on the mainland of Chiriquí Province, but may exist in a narrow belt along the coast under alluvial cover or on the islands. It would appear that the invasion of the sea took place northeast to southwest, suggesting that the sea advanced over a fault block which was sinking more rapidly on the northeast side. This agrees with present structure of the Burica Peninsula, which consists of a series of fault blocks tilted toward the northeast, and it indicates that such structures may exist far to the southwest beneath the sea (fig. 6).

The Corotú well encountered no conglomerates other than the basal conglomerate; but other conglomerates are found in the interior of the peninsula, especially to the northwest along the strike. Since the section is repeated by faulting, it is probable that some of these occurrences are merely repetitions. Nevertheless the section appears thicker to the northwest and the portion between the Eocene limestone and the first conglomerate above the basal one has been differentiated on the map (pl. I, and fig. 6) as middle Miocene and giving the tentative name of the La Vaca formation. It is believed to be the equivalent of the part of the Chareo Azul below 5,400 feet in Brixey's division, where the middle Miocene would have only member status.

In the Corotú well, 7,785 feet of sediments was encountered. The field work indicated that about 1,100 feet of the formation had been removed by erosion at the well site, making a total of 8,885 feet, a figure reduced by the fact that the dipmeter readings indicated dips of  $8^{\circ}$  to  $20^{\circ}$  at various points in the hole. Allowing for this reduction, the total thickness of the formation would be between 8,000 and 8,500 feet, probably nearer the latter. Of this thickness about 2,700 feet would be undisputed Pliocene, 3,500 feet Mio-Pliocene, and 2,300 feet undisputed Miocene. All paleontologists who have worked on the Chareo Azul fauna have noted the moderately deep to deep-water

character of the fossils. This is also borne out by the lack of coarse sediments, except at the base.

On the Caribbean side, the Pliocene is represented by a group of coarse sandstones and soft shales near Puerto Limon, Costa Rica, from which Gabb (1881) described a molluscan fauna; and by the boulder conglomerates of the Talamanca valley and adjacent regions in Bocas del Toro and Costa Rica. Olsson (1922) has noted the presence of interbedded thin blue clays among these conglomerates, carrying a small fresh-water fauna. On the northwest coast of Columbus Island, Bocas del Toro, Pliocene coral-reef limestones with interbedded bands of marly shale have been found in small outcrops [Olsson (1922)].

#### PLEISTOCENE

The Pleistocene of central Panama, identified only in the Canal Zone, consists of muds along the coast east of Colon and in Limon Bay; it is also found in borings in the northern part of the Canal Zone. They are littoral and swamp deposits. They have been described by MacDonald (1919), Woodring and Thompson (1949), and Jones (1950).

Pleistocene has not been recognized in eastern Panama, although no doubt present over large areas. In western Panama a group of soft clays with layers of sand, outcrops in Rio Rabo de Puereco and Monte Verde ravine near Puerto Armuelles. In Rabo de Puereco a conglomerate forms the base of the formation. The total thickness is unknown, but apparently exceeds 600 feet. The upper part of the formation lies offshore or beneath the alluvium to the east. The base of the formation is found inland up to elevations of 100 feet or more above sea level. From these beds Olsson (1942) has identified 113 species.

#### RECENT

Recent deposits consist of stream deposits or outwash from volcanic elastics or other unconsolidated rocks. For the most part they occur on the flood plains of streams or along the coast or in swampy areas or pocket valleys such as the Talamanca Valley, close to steep mountain slopes. In such localities they often form boulder and gravel fans, but in general they are sands, silts, or muds, and are flat or with gentle slopes.

#### STRUCTURE

Central America from Salvador to northern Costa Rica, including eastern Honduras, Nicaragua, and northern Costa Rica, is here con-

sidered to form the western end of the Caribbean arc, of which the other visible features are the Greater Antilles and Lesser Antilles, which are separated from northern South America by the Caribbean basin, an arcuate submarine depression with a maximum depth of something over 5,000 fathoms. The Caribbean arc is considered by many geologists and geophysicists to be a typical representative of the Pacific island arcs, the features of which have been set forth by Gutenberg and Richter (1949), as follows:

Beginning on the convex side of the arc

A—An oceanic trench

B—A narrow belt of shallow earthquakes and negative gravity anomalies, on the concave side of the trench. This belt frequently rises in a ridge, which may emerge into small nonvolcanic islands.

C—A belt of maximum positive gravity anomalies, with earthquakes, frequently large, at depths near 60 km.

D—The principal structural arc of late Cretaceous or Tertiary age with active or recently extinct volcanoes. Shocks at depths of the order of 100 km. Gravity anomalies decreasing.

E—A second structural arc. Volcanism older and usually in a late stage. Shocks at depths of 200–300 km.

F—A belt of shocks at depths of 300–700 km.

Details vary widely from region to region, often one or more features are poorly represented or unknown.

When these features are combined in a diagrammatic section, they suggest that a typical island arc is underlain by a sloping fault plane or zone of fault planes which emerges at the oceanic trench and dips toward the concave side of the arc. The mechanism has been described by Benioff (1949), the activating agent being the dense oceanic block underthrusting the lighter continental block. The Caribbean arc at its northern front presents the trench, the belt of negative anomalies, the shallow shocks, and a belt of maximum positive anomalies, but no active volcanoes. At its eastern end, the Lesser Antilles, it presents a trench (not deep), a belt of negative anomalies, and a belt of active volcanoes. At its western end, Central America, is a trench (depth, 4,000 fathoms), a belt of shallow shocks, a belt of active volcanoes, and a belt of intermediate shocks. The typical gravity anomalies may exist, but are unknown. These conditions extend from Salvador to northern Costa Rica, but in southern Costa Rica and Panama there are new and confusing factors.

There are no active volcanoes in Panama, although there was volcanic activity from the Eocene to the Pleistocene. Gravity anomalies have not been recorded. The convexity of the structural and topographic forms is mainly toward the Caribbean arc, rather than away

from it, as at other points in its perimeter; but there is evidence of local convexity to the southwest. The ends of the northeastwardly convex arcs appear to extend to the southwest as submarine swells across the floor of the Pacific into a region described by Gutenberg and Richter (1949) as of continental structure, although at present submerged. The northeastwardly convex arcs are cut by a series of radial arcuate faults convex to the west. When these faults are projected north and northeast across the Caribbean basin they appear to border topographic swells and troughs. With these facts in mind, we may take up the consideration of local structure.

#### EASTERN PANAMA

Central and eastern Panama show a series of concentric structural arcs, convex to the north, cut by a series of trans-isthmian faults which intersect the concentric structures radially (fig. 4). The northernmost of these structural arcs forms the continental divide from the Colombian boundary to a point a few miles east of the Canal Zone. The core of the divide is the basement complex. Over much of its length, its outer (northeast) flank lies in the territory of the Cuna Indians, whose attitude toward strangers prevents geologic field work in their territory except under military protection. In 1870, the Selfridge expedition crossed from Caledonia Bay to the Chucunaque River, under such protection, and the mineralogist of the expedition, Carson (1874), reported sandstone on the outer (northeastern) flank of the ridge. In 1947, geologists in the service of the War Department crossed on the same route, and while no report has been published of their work, the writer has been informed that Carson's observation was verified. The writer has flown over this stretch of coast several times, he has walked across the Isthmus from Chepo to the Gulf of San Blas, and he has studied the air photographs. Over considerable stretches, the continental divide is paralleled on the outer (northeast) side by a series of low ridges, such as would be formed by tilted sedimentary strata. On the southwestern side of the divide the sedimentary rocks dip away from the divide at fairly low angles. The impression gained by the writer is that the continental divide is an asymmetric anticline with the steep side toward the Caribbean. About halfway between Nombre Dios and Punta San Blas, on the Caribbean coast, coarse sandstones of unknown age stand on edge striking E-W.—Schuchert (1935).

From the head of the Gulf of San Blas westward, the rocks on the north side of the divide belong to the basement complex, until the Madden basin is reached, where the divide is seen to be the escarpment forming the south limit of the Madden graben. The fact that

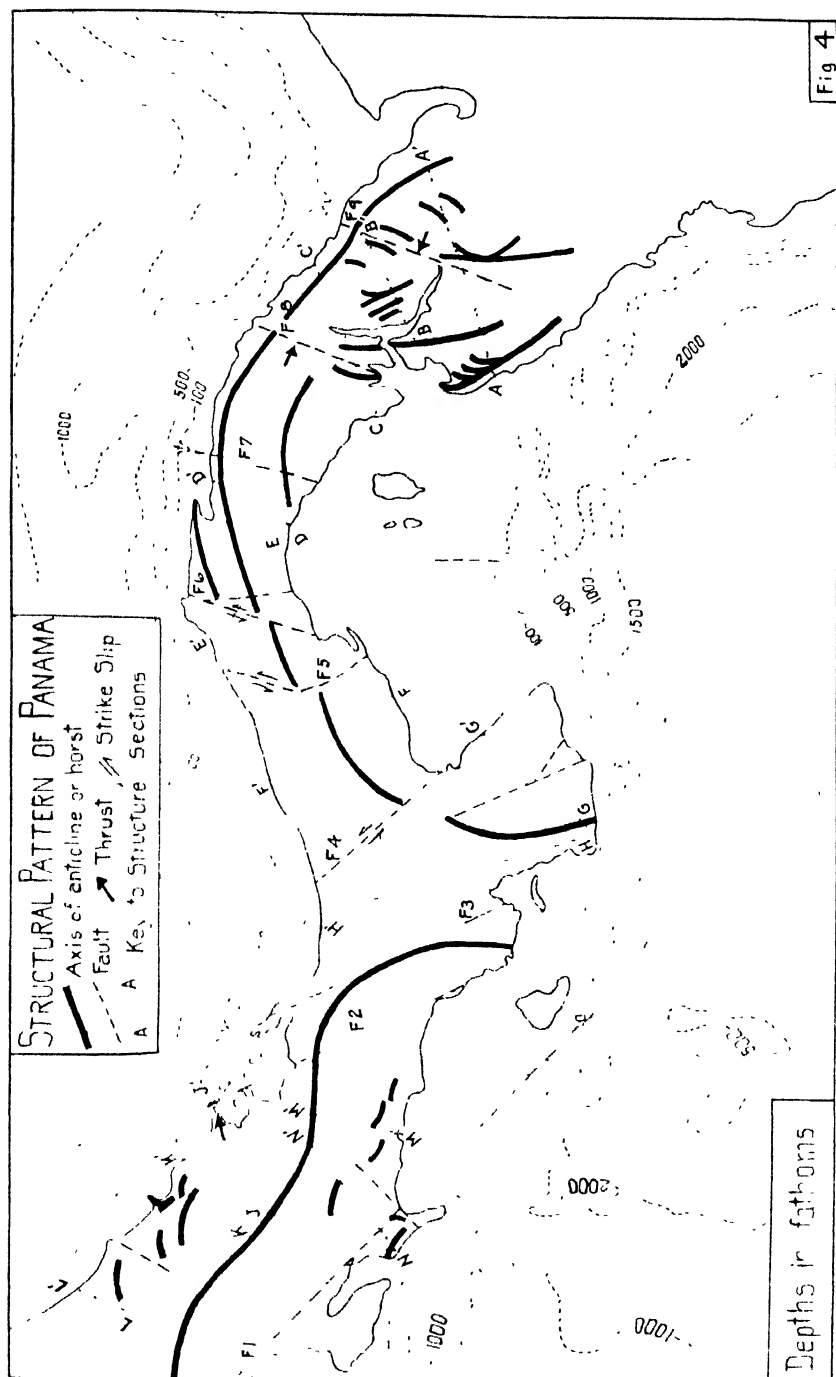


Figure 4. Structural pattern of Panama, with a key to structure sections shown in figures 5 and 6.



the divide is here paralleled by a fault on the north side suggests that it may be so paralleled for much more of its length.

The continental divide east of Chepo is paralleled to the south by another igneous ridge which forms the divide between the Bayano River basin and the Pacific. The rocks on the south side of the latter ridge are Oligocene shales dipping southwest at low angles toward the Pacific, where seen by the writer on Rio Pásiga and Rio Chimán. The rocks of the northeast side are also sediments, but their attitude is unknown. The ridge appears to be anticlinal.

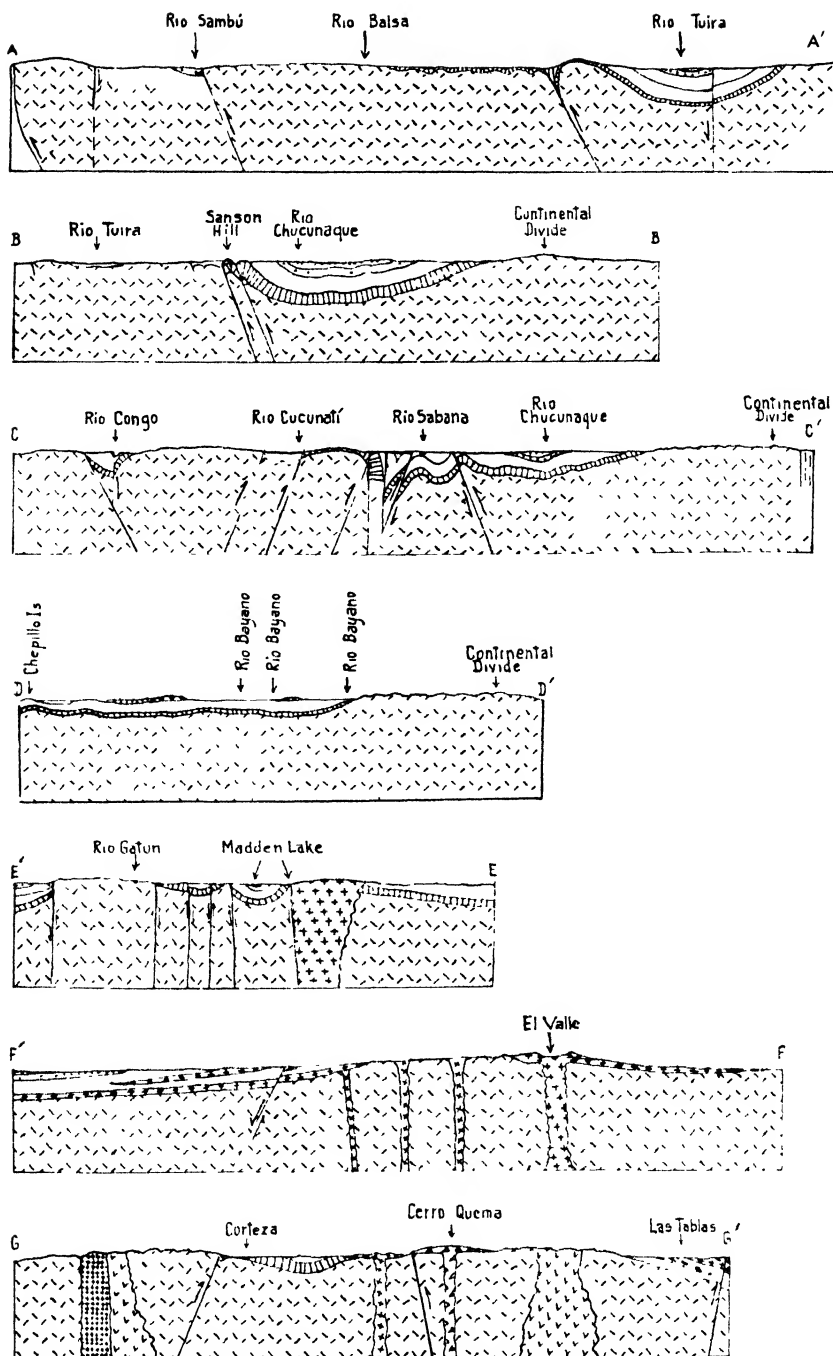
In central Darien Province, the structural situation is quite different. In the area west of the structural trough occupied by the Tuira and Chucunaque rivers, is a group of tightly folded asymmetric anticlines, with their steep sides facing west and in several cases bordered by thrust faults dipping east. Of this group, the largest is the Pirri anticline, which separates the basin of the upper Tuira from the basin of the Balsa. The core of the anticline is the basement complex, from which the sediments dip to the southeast at low angles on the east side; they stand on edge on the west side, which is cut off by a thrust fault, striking about N. 25° E. (Pl. 9, fig. 4). The angle of dip of the thrust fault is apparently high (structure section A-A).

North of this and west of the Chucunaque River lies a conspicuous ridge, which is also the core of an asymmetric fold, the Sanson anticline, which consists of vertical Oligocene and Eocene strata on the west flank and the same formations plus the Miocene on the east flank, dipping east at angles of 5° to 45°. The fold is cut off at its western foot by a thrust fault striking N. 25° W., and a drag fold on its eastern flank is cut off by a parallel fault (structure section B-B). From the Sanson anticline to the estuary of the Rio Sabana only some very sketchy reconnaissance notes are available. The rocks are apparently Oligocene and Eocene, tightly folded and faulted and standing at steep angles mostly from 60° to 90°. The outcrops are separated by swampy areas, as the entire region has been deeply eroded, much of it based leveled. It appears that the outcrops represent portions of tight asymmetric folds, striking N. 25° W., pushed toward the west. The air view and air photographs support this impression.

Crossing the Rio Sabana and ascending its tributary from the west, Quebrada Los Nunos, the Aquagua black shale (early Miocene) appears standing on edge or dipping steeply to the west near the Sabana, followed by vertical Oligocene and Eocene strata with a variety

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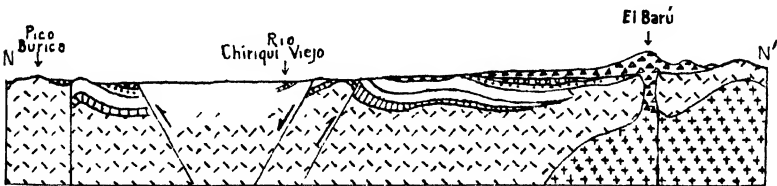
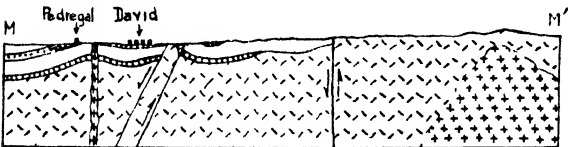
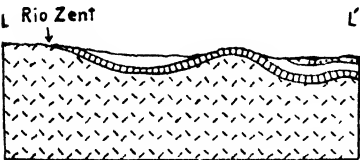
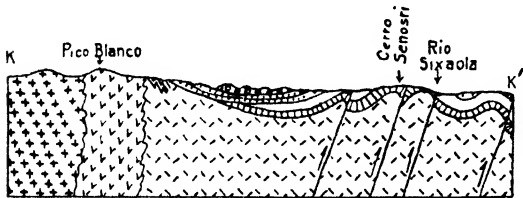
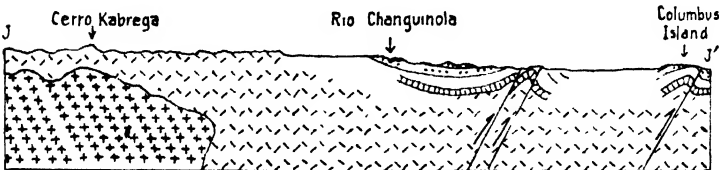
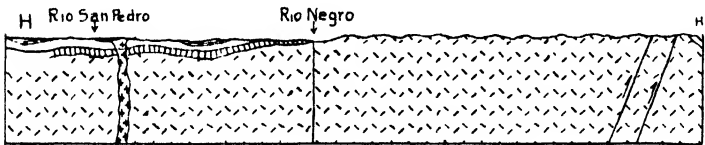
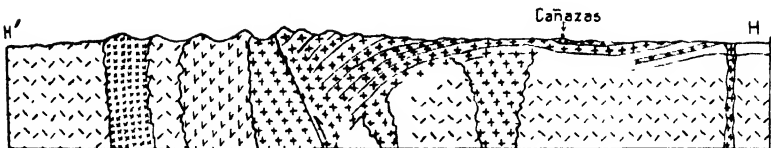
Figure 5 Structure sections. See figure 4 for the location of these sections. See plates I, II, and III for an explanation of the symbols used to represent the formations shown here.



of strikes of which N. 25° W. to N. 30° W. are the most common. Something over 4,800 feet of Oligocene and Eocene limestones and shales with interbedded volcanics is exposed before reaching the crest of the divide between Rio Sabana and Rio Cucunatí drainage. Here the strata flatten out and on the west side dip at low angles toward the Cucunatí. On the west side of the Cucunatí valley this low-dipping westward inclined Eocene is cut off by a cliff of basement andesite. The contact is apparently a thrust fault (F. 8), or series of thrust faults dipping west at a high angle (structure section C-C), (F. 8, fig. 4). The section between the Sanson and the Cucunatí is one of the mostly tightly compressed and intricately faulted areas between Lake Nicaragua and the Atrato River, fronted on each side by an advancing overthrust and broken into a mass of squeeze blocks which would be almost impossible to map in detail. The soft Oligo-Miocene shales are so incompetent that a section 3,000 to 4,000 feet thick may be squeezed down to 1,000 to 2,000 feet and the fault breccia of the competent limestones, cherts, and tuffs crowded into this from each side. Much of the area has been baseleveled by erosion, and is now a swamp barely above the level of high tide. In these portions, the structure is, of course, unknown. However, the Cucunatí fault zone can be traced across the Isthmus. The writer has visited it as far north as the head of the Rio Sabana where the soft brown Gatun sandstones stand on edge striking N. 25° E. The fault zone crosses the Chucunaque in the "forbidden land" of the Cuna Indians, but from the air a conspicuous bulge of the mountains of the continental divide can be seen crowding southwest and narrowing the sedimentary valley of the Chucunaque by several miles. In spite of this narrowing and crowding, no conspicuous ridge marks the divide between the heads of the Artigartí (Chucunaque drainage) and the Cañasas (Bayano drainage). The writer has flown repeatedly over this area in a small airplane at an altitude of 800-900 feet, and neither he nor the pilot of the plane could detect the divide between Bayano and Chucunaque drainages. The region has been peneplaned and both streams are meandering in such an intricately interlaced pattern that in many places it was hard to tell whether the drainage was to the north or south. This peneplanation must have taken place after the fault movement had ceased, indicating that the stresses which caused the faulting had ceased before the end of Pleistocene time, and probably considerably earlier.

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Figure 6. Structure sections (continued). See figure 4 for the location of these sections. Structure sections H'-H and H-H should be joined to form the complete cross section; Cañasas is on the Caribbean half; Rio Negro is on the Pacific half. See plates I, II, and III for an explanation of the symbols used to represent the formations shown here.



The southern part of the Cucunatí fault zone appears to pass through San Miguel Bay and across the continental shelf, and from the edge of the continental shelf to turn south into the head of the 2,000-fathom trench which parallels the coast of northwestern Colombia and Ecuador. The curve of Garachiné Point from northwest to northeast suggests that there has been a strike slip along the fault, the east side moving south, and the west side to the north. This strike slip, however, is only part of the movement. The overthrust from the northwest, or underthrust from the southeast, was evidently the first and major movement, and the present arrangement of the outcrops is the net result of repeated movements, not all in the same direction.

The parallel Pirri fault (Pl. 9, fig. 4), 45 miles to the east, also shows some indication of a strike slip, the east side moving south as in the Cucunatí fault. It is possible that this apparent strike slip may be actually a secondary effect of the thrust. The Pirri fault is traceable into the Gatun outcrop at the point where it crosses Rio Tuira about a mile east of Real, but is less evident in the Puéro and still less in the Chucunaque, indicating that its main movement took place in Gatun time.

West of the Pirri anticline the valley of the Rio Balsa is filled in its lower half by alluvium over folded Tertiary sediments, mostly Eocene. The upper half of the valley is occupied by igneous rocks of the basement complex. West of the Balsa valley, an area of basement rocks separates it from the Sambú valley. These basement rocks contain small unfaulted areas of Eocene limestone. At the west edge of this block, the basement rocks are terminated by a fault striking N. 30° W., forming the east side of the Sambú valley, which is filled with Tertiary sediments dipping east at low angles, and between this sedimentary area and the sea is another area of basement complex, terminated at the coast by another fault. At intervals along the coast Oligocene-Miocene shales appear, standing on edge (structure section A-A).

The structure of Darien south of San Miguel Bay and west of the Tuira, thus appears as a series of three fault blocks tilted toward the east and cut off on their western edges by faults. One of these blocks, the Pirri block, is known to be an asymmetric anticline with its western flank vertical or overturned. It is believed that the two blocks west of it are of the same type more deeply eroded, and that the faults which cut them off at their western edges are steep angle thrusts dipping east. It is believed, also that these faults are splinter faults from the Cucunatí fault zone.

The continental divide is believed to be an asymmetric anticline with the steep side toward the east. The fact that it is apparently offset where intersected by the transisthmian faults indicates that there has been movement on these faults since the anticline was formed. However, late Miocene sediments are not much affected by these faults.

An interesting structural feature of eastern Darien is a series of small anticlinal noses in echelon along the east side of the Chucunaque-Tuira basin. They extend in a NE.-SW. direction and are slightly arcuate, convex toward the southeast. On the opposite side of the basin, a similar anticlinal nose branches from the Sanson anticline on a NE.-SW. strike. Farther south, a drag fold rising on the eastern flank of the Pirri anticline near the village of Aruza, strikes first north and then northwest, crossing the Tuira River about a mile east of the village of Pinogana and continuing across the basin on a N. 65° E. strike.

Darien displays little seismic activity. Gutenberg and Richter (1949) list only four epicenters, one of which (9° N.-78° W.) lies near the Cuenmatí fault near the Caribbean coast. This shock is described by Kirkpatrick (1939) as the "most pronounced shock of instrument record at Balboa. It was felt generally throughout the Republic." Gutenberg and Richter list it as of intermediate depth and of magnitude 7.2. Another heavy shock, of which there is apparently no instrument record, took place on September 7, 1882, in which the Cathedral in Panama City, and several other buildings suffered some injury. Part of the old municipal building fell and the Panama railroad suffered some damage. This shock is believed to have originated off the San Blas coast, as Mr. Fred McKim (1947) was told in 1936 by one of the oldest Indians that in his boyhood a great wave swept over the island on which he lived, destroying all the houses and causing some loss of life. This is the only record of a tsunami east of the Canal Zone, and is believed to indicate a movement of the sea bottom in or near the Gulf of San Blas.

#### CENTRAL PANAMA

The next important transisthmian fault zone is in and adjacent to the Canal Zone; it is probably the fundamental reason the canal is where it is. There are apparently several of these transisthmian faults in a belt crossing the isthmus and emerging between Nombre Dios and Rio Indio on the Caribbean side and between Old Panama and San Carlos on the Pacific side. They are in some cases arcuate, convex to the west, and vary in strike from N. 20° E. to N. 30° W., crossing the continental divide in most cases on a nearly N.-S. strike. The divide

itself in this region is almost entirely in extrusive igneous rock in which structure is difficult to detect. The rocks are believed to be mostly Oligocene and Miocene; and are bordered on the north by late Oligocene and Miocene sediments dipping north in the region west of the Canal. On the Pacific side clastic volcanics of probable Miocene age dip toward the sea, where dip can be seen. Gravity determinations by Wuenschel, reported by Jones (1950) showed the highest positive anomalies on the basement complex east of the Zone, and increasingly negative anomalies westward as far as Chorrera, which Jones interprets to mean that these areas are underlain by lighter Tertiary rocks, and that "the Tertiary cover over the Pre-Tertiary basement is thicker toward Chorrera. The isogals strike E.-W." Jones also indicates the Chorrera basalt is of uppermost lower Miocene age, implying that the thickening of the Tertiary section must be in the lower Miocene, Oligocene, or Eocene. The continental divide is about seven miles north of Chorrera and runs N. 70° E., so that the E.-W. isogals are nearly parallel to it. This would indicate that the divide is anticlinal, with the sediments thickening seaward on the Pacific side, as well as on the Atlantic.

The Caribbean ends of several of the transisthmian faults are indicated on Jones' map (1950), the principal one passing through Limon Bay, along the west shore of Gatun Lake for about eight miles, crossing the lake and entering Trinidad River south of the lake. It apparently controls the course of the Trinidad to the continental divide following an arcuate course, convex to the west. Immediately east of it, the continental divide parallels it in a general N.-S. direction for some fifteen miles, almost at right angles to its normal N. 70° E. course. It seems unlikely that this 15-mile right-angle shift of the continental divide resulted from strike slip along the fault, but, the faulting undoubtedly controls its location. South of the divide the fault enters the granite of the Campana area, which is cut by three deep parallel valleys (beautifully shown on the air photographs), one of which leads directly up to the notch at the head of Rio Trinidad, and is undoubtedly due to the continuation of the fault on a S. 30° E. strike, which carries it out to sea just west of Chame. A continuation of the strike across the continental shelf leads directly to the notch in the edge of the shelf south and west of the Pearl Islands, and to the head of the trench paralleling the coast of northwestern Colombia.

An interesting fault valley (F. 6) parallel to that just described is occupied by the Boqueron River north of Madden Lake. It is in fact a narrow graben striking N. 20° E. across the basement complex, and is of particular interest because it contains the only manganese

deposit in Panama which has been worked at a profit. This deposit has been described by Sears (1919), who says it occurs in a sedimentary complex of shales, sandstones, and limestones, which he does not identify as to age, but says they are older than the sediments outcropping downstream, which are late Eocene. They occur in the valley of the Rio Diablo, the tributary of the Boqueron nearest its head. The sediments show such a confusion of dips and strikes that Sears was unable to determine their sequence. The faults bordering this graben can be seen in the Eocene limestone and basement complex at the head of Madden Lake.

Other NE.-SW. faults can be seen in the Madden Lake basin and a very prominent set of parallel faults striking N. 70° E.-S. 70° W. intersect them, outlining opposite sides of the depressed fault block occupied by Madden Lake. This last set of faults is very persistent. They apparently extend eastward to the Caribbean, where they outline the Gulf of San Blas, and Jones (1950) shows some of them extending west to the edge of his map, south of the middle of Gatun Lake. Some of them extend across the Rio Indio coal fields as shown in the figure, where they intersect a group of N.-S. faults. The regional dip is of the order of 10° or less, but where the coal is intersected by the faults, the dips are from 40° to 60°. A dike on one of the N.-S. faults is intersected by two of the N. 70° E. faults, and the ends of the dike twisted east at the south end and west at the north end. Strike slip is shown by these ends of the dike and by the corresponding shifts of the coal bed. The indicated movement is left lateral. In the Boqueron manganese deposit the only dip recorded by Sears (1919) is one in which the limestone is standing on edge striking N. 70° E., obviously on one of the series of N. 70° E. faults.

Still farther west, the N. 70° E. series of faults reappear along the north flank of the continental divide, where they are shown in the structure section by Hershey (1901) (reproduced with slight modifications in structure section II-H). At the heads of Rio San Pablo, Rio Cobre, and Rio Tabasará, a series of parallel arcuate valleys convex to the northwest apparently mark the position of a series of splinter faults along the northwestern edge of the central Panama arcuate structural system.

The group of arcuate faults along the upper Tabasará, Cobre, and San Pablo rivers and their branches has attracted some attention as the locus of copper prospecting in Panama. The copper occurs as low-grade sulphide ores carrying gold (Riddell (1927)).

The continental divide in central Panama west of the head of Rio Indio follows close to the north rim of El Valle volcano, and its south



flank for some miles is concealed by the ejecta from that crater. About 20 miles to the west, near the village of La Pintada, andesite flows dipping to the northwest are overlain to the south by rhyolite flows and tuffs dipping south at a low angle. The northwest dip of the andesites can be seen along the edge of the hills bordering the west edge of the plain which extends from Penonomé southward to the coast. The Pan-American Highway from Penonomé to Natá follows a course approximately parallel to and a little southeast of an arcuate anticlinal axis, on the northwest side of which the andesite flows dip to the northwest, while on the southeast side the rhyolite flows dip to the southeast. This axis appears to be the continuation of the anticlinal axis which forms the continental divide east of La Pintada. It can no longer be followed after entering the coastal plain a few miles north of Aguadulee, but on crossing the plain in a southwesterly direction it can be picked up again. At Pesé, Oligocene calcareous shales dip northeast, while about seven miles to the west near Oeú they lie nearly flat apparently on the anticlinal axis, and farther west near the head of Montijo Bay they dip northwest. South of Pesé in the vicinity of Macaracas, the dip of the Oligocene and Miocene changes from northeast to east and to southeast as one goes south (Joukowsky and Clere (1906)). It appears that an anticlinal axis run-

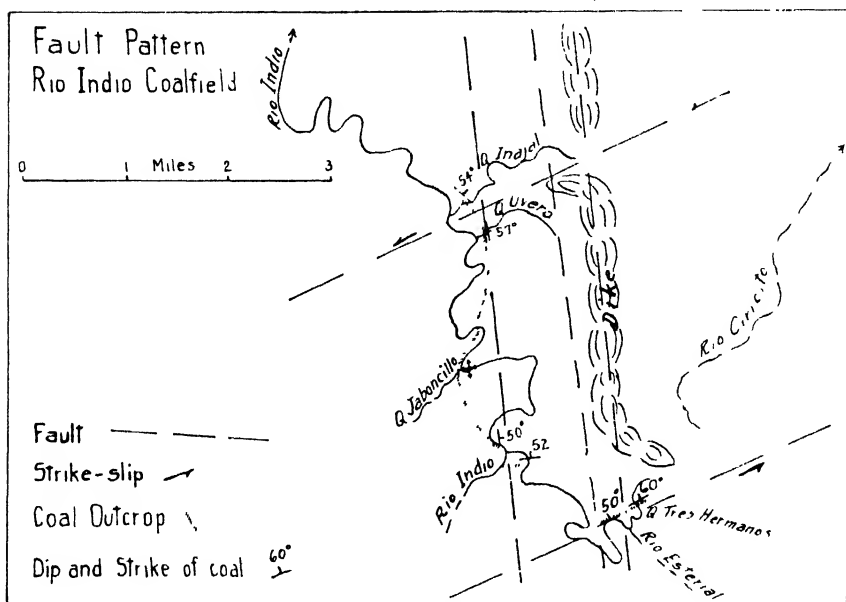


Figure 7 Fault pattern—Rio Indio coalfield.

ning NE.-SW. through Oeú continues southwest to the coast at some point east of Punta Mariato and west of Morro Puercos. The greater part of this region is basement complex bordered on the west by a narrow band of Eocene and Oligocene sediments along the east shore of Montijo Bay, and on the east by the Eocene and Oligocene of the Tonosí valley. The Tertiary sediments curve round the nose of the igneous northeast of Oeú, and near Las Tablas can be seen to dip underneath another band of andesite flows which border the east coast of the Azuero Peninsula. These andesites are believed to be a part of the same group of flows as those which appear west of the road from Penonomé to Natá.

Whether the anticlinal axis described above was originally continuous with the one extending southwest from La Pintada is not known. At any rate they are separated by a transisthmian fault (F. 4, fig. 4) striking N. 42° W., which can be clearly seen from the air or on the air photographs, although difficult to trace on the ground as it traverses a low flat region of swamps and coastal plain from Aguadulce south. To the north it cuts across the isthmus in a region entirely igneous. Its course to the south can be located by a succession of dikes, shifted stream courses, and small linear depressions, on the eastern coast of the Azuero Peninsula; and where its extension crosses the edge of the continental shelf, it is marked by a deep reentrant as far as the 1,000-fathom isobath, but can not be traced farther. Whether this fault belongs to the same system as the arcuate transisthmian faults farther east is not apparent.

The anticlinal, described above, which occupies the west side of the Azuero Peninsula is cut by a great number of faults, only a few of which are shown on the map. The commonest strikes are from N. 25° W. to N. 55° W., but there also are numerous others on various strikes. The writer is indebted to Dr. E. R. Dunn of Haverford College for the following notes on a region on which there is practically no other information. His letter reads:

I have had my rocks determined at the Bryn Mawr Geological Laboratory, and this is about what I have to report

We went pretty nearly straight south along Oeú, Las Minas, and thence south along the divide. At first this was pretty straight and we didn't have to cross much water, but later it began to swing very widely

1. At Oeú sedimentary rocks were exposed, lying almost horizontally. The terrain is pretty flat and it is savanna country. Altitude 300.

2. We got into hills before we reached the Parita River. At the river sedimentaries were exposed, lying nearly vertically with an E-W strike. Altitude about 300.

3. Around Las Minas we saw quite a bit of manganese ore and of course

there was a gold mine there once, with pretty old workings but I imagine there is plenty of dope on that.

4. Rock was exposed in the bed of the Quebrada Piedra, some 20 miles south of Las Minas. This stream was said by Davies to enter the La Villa (the river which forms the border between Herrera and Los Santos). This was andesite at an altitude of about 1,500.

5. North face of Mangillo partial section. Altitude about 2,500 to 3,000. Bottom (Davies saw this, I didn't), sedimentaries dip  $50^{\circ}$  W., strike N.-S., then andesite (I saw this and have a piece), on top of the andesite sedimentaries, limestones and shale, dip  $30^{\circ}$  S., strike E.-W. (I have some of this). This was exposed in the bed of a small stream running north to Queb. Piedra. There is no doubt of the sedimentaries on top of the andesite. Exposed on the top of Mangillo was some andesite, thus andesite both above (since the top was south of the stream exposure) and below the sedimentaries I saw, and if Davies is right, and I see no reason why not, you have from bottom up, andesite, sedimentary strike N.-S., andesite, sedimentary strike E.-W., andesite.

6. Going south from Mangillo, on side of a long ridge, at head of a small stream, rhyolite was exposed at about 2,000. Stream tributary to Rio Quebro.

7. At Dos Bocas, 375 feet where the Quebro really starts as a combination of a big stream coming from the west and another coming from the east (the one from the west rises on Cerro Negrito and is mapped as running west) there were many granite boulders in both branches, obviously coming from somewhere upstream. Alluvial gold was present.

8. The exposed rock at this place, forming the walls of the canyon, was a smooth green serpentine.

From Las Minas south, we crossed east-west ridges in the following order: Penalosa, Buenavista, Jacinto, Piedra de Tigre, Macaracito, Mangillo. We had to cross the head of a small west-flowing stream (tributary to Negro-Mariato) to reach Macaracito, which ridge was said to run down to Macaracas. We had to go down pretty far and cross a larger east-flowing stream (tributary to Lavilla) to get to Mangillo. Beyond Mangillo we had to go down to 375 feet and hit the canyon of the west-flowing Quebro.

From the situation at the Parita, and on the north slope of Mangillo, it looks to me that these ridges are structural and based on tilted (folded ?) sedimentaries, interspersed with volcanics and based on intrusives.

Davies says that the serpentine at Dos Bocas (which he called dunite) is exposed in Cerro Negritos near the west coast.

At any rate, there are tilted sedimentaries in the very middle of the peninsula at 2,500 feet.

The rock exposed on top of Cacaranao, 3,300, looked like the rock on top of Mangillo (andesite).

Dunn's notes on serpentine and dunite are of particular interest, in view of Hess's theory of the relation between serpentized basic rocks and the course of old island arcs.

The eastern half of the Azuero Peninsula is also occupied by an anticlinal axis, arcuate and convex to the northwest. In the axial region,

granite is exposed, with heavy basic igneous rocks to the east. It is bordered on the west by the Tonosí valley Eocene which is connected with the Tertiaries to the north by a narrow corridor of Oligocene and Miocene in the region of Macaracas. This sedimentary band is overlapped in the southeast by volcanics partly from Cerro Quema, which MacDonald (1937) considers a Pleistocene volcano.

The continental divide west of La Pintada is not anticlinal, but apparently consists of a series of fault slices striking NW.-SE. cutting the andesite flows and dikes at the top of the Oligocene-Miocene sequence which farther southwest is interbedded with sediments of that age. The orientation of stream courses is interesting. The rocks on both sides of the divide are igneous, those on the north being granite, syenite, and andesite in the region of Mineral and to the west, and on the south side the andesite flows mentioned above. Seen from the air, the north side is a series of precipitous ridges, separated by deep narrow canyons, which instead of running straight to the sea as might be expected in a region of igneous rocks of great relief close to the sea, form a parallel series at an acute angle to the sea on a strike of about N. 45° W. They appear to be caused by parallel faulting. South of the divide the streams run in courses S. 70° W. parallel to the divide and gradually curve more to the south in their lower part. Some sharp changes in the course of the divide are probably due to faulting. However, the region has not been studied, and although there has been a good deal of mining going on ever since the Spanish conquest, there are few references in the literature to regional structure, aside from Hershey (1901) and Wagner (1862). Taylor (1852), however, indicates that the rocks show stratification, and refers to "porphyroid, pyritous, ferruginous, granitoid trap," and on his map shows the contact of porphyry and trap running about N. 85° E. near the mouth of Rio Escribanos near Belen, and shows the strike of the gold-bearing quartz veins as parallel to it, suggesting that there may be a fault system causing the structure. In view of the fact that granite and syenite, mentioned by Wagner (1862) and Hershey (1901) in the coastal region near Mineral, are considered by all the geologists with the exception of Gabb (1875), to belong to a pre-upper Eocene complex, the map (pl. II) represents this area as basement complex.

The Azuero Peninsula is second only to southwestern Chiriquí as a locus of seismic activity. The greatest and most destructive activity took place in 1913, and was investigated by MacDonald (1913), whose account was published in the Canal Record of December 10, of that year. The epicenters shown on the map are based on MacDonald's work. The fault along the east coast of the Azuero Peninsula is ap-

parently the cause of many small shocks recorded on the Balboa seismograph.

The arcuate form of the major structural features of central and eastern Panama resembles that of a typical island arc of the Pacific type, and the occurrence of serpentine and dunite on its outer flank in Veraguas conforms to Hess's theory of the association of such rocks with belts of negative gravity anomalies in the island arcs of the East and West Indies. However, nothing is known as to the distribution of gravity anomalies in Veraguas.

### WESTERN PANAMA

In western Panama, as in eastern Panama, there are a series of arcuate antilinal and synclinal folds. They are convex to the northeast, for the most part, but volcanic ejecta of Pliocene and Pleistocene age in enormous amount have concealed the structure of the Tertiary sediments over much of the area. Volcanics of contemporary origin are also interbedded in the Oligocene and Miocene sediments, but perhaps to a lesser degree than in central Panama. The two arcuate structural systems of eastern and western Panama are separated by a fault (F. 3, fig. 4), running N. 24° W. from Montijo Bay to the Valiente Peninsula, and other faults on the same strike occur to the west of it. The writer crossed this area from the head of navigation on Rio Cricamola to San Felix. No sedimentaries were observed north of the divide, but they may be concealed under the alluvium of the coastal plain which is three or four miles wide. The observed rock in place south of the coastal plain along the Cricamola was andesite, but no structure could be detected until the continental divide was reached where flat-lying lava beds were observed. On the south side of the divide, slopes of very fresh volcanic ash were crossed, the Indians who accompanied the writer spreading out along the path to avoid starting a slide. The first sediments were observed about seven miles south of the divide where foraminiferal shales of Oligocene age dipped south at a low angle. They appeared to be interbedded with volcanics, but all rocks seen were so deeply weathered that it was difficult to distinguish the tuffaceous shales from the tuffs. The age of the beds was inferred from a *Glyptostyla* cf. *panamensis* collected by Olsson some miles north of San Felix. The contact of the sediments with the igneous is known to be a few miles east of Tolé, and to reach the sea near the mouth of Rio Tabasará, but the region has not been mapped in detail. The contact apparently follows an arc convex to the northeast, suggesting that it is following the curve of an antilinal axis to the east. The axis connects the Soná Peninsula (believed to be base-

ment rocks from the presence of the bedded cherts at Bahia Honda), with the continental divide near Cerro Santiago, and is thus, structurally and petrographically, the continuation of the continental divide of Chiriquí and Bocas del Toro, although it is no longer the continental divide. The southwestward trend of the isobath contours off the coast indicates that the structure continues out to sea in that direction. The continental divide from Cerro Santiago east is apparently a series of fault ridges without anticlinal folding.

Folding on lines approximately parallel to the continental divide takes place on both sides of the isthmus in western Panama, two general zones of folding being present on each side; and there are many faults. Most of the folds on the Caribbean side are asymmetric with the steep side toward the sea, and in several cases are faulted on the steep side, with a strong suggestion of thrust faulting. In one case this suggestion was confirmed by drilling. On Columbus Island, at the northwestern end of Chiriquí Lagoon, the surface structure was interpreted by geologists as a gently rounded dome on which the early Miocene Conch Point shale outcropped at the crest, over an area perhaps a mile in diameter, surrounded by the Bastimentos shale of middle Miocene age. A seismograph survey indicates that the structure is cut by a fault striking N 24° E. (F. 2, fig. 4).

The result of drilling is indicated in the following excerpt from a report of the paleontologist, A. D. Brixey, Jr., who examined the well cuttings:

Excellent proof of thrust faulting within the Bocas del Toro dome section occurs between 1,630 and 2,520 feet and between 4,350 and 4,570 feet, respectively. At 1,630 feet a zone of fossilized, large (2-4 mm.) flat seeds (Seeds A) is followed by a zone of *Virgulina* sp. a, and a zone of *Siphonodosaria* sp. a at 2020 ft. At 2,120 Seeds A recur, followed by *Virgulina* sp. a at 2,370, and another zone of *Siphonodosaria* sp. a at 2,520. This would indicate thrusting of a section of 390 to 400 feet.

The second phase of major thrusting between 4,350 and 4,360, a sandy facies, poor microfauna with the exception of a rather small *Globigerina bulloides* followed by a zone of *Amphistegina lessona* and an abundance of *Miliolidae*. Again between 4,530 and 4,540 a sandy facies was noted, a poor microfauna followed by small *Globigerina bulloides* and a zone of *Amphistegina lessona* and *Miliolidae*. Another zone of possible thrusting occurs between 6,360 and 6,380 feet and 6,750 to 6,780 feet where the microfauna again show a significant repetitious similarity.

In addition an unprecedented thickness of the Conch Point shale was encountered. The measured thickness of the Usuari (the inshore equivalent of the Conch Point) rarely exceeds 5,000 feet, and was nowhere estimated at over 6,000, but the well penetrated 8,621 feet and

was abandoned because of drilling difficulties in heaving shale, without reaching the base of the formation. A dipmeter reading at about 4,500 feet gave a dip of about  $25^{\circ}$  to the southwest, and cores showed even higher dips. It seems obvious that the structure of Columbus Island includes a series of thrust faults. If a fold is present it is asymmetric with the steeper side toward the Caribbean.

The largest inshore anticline mapped is Senosri Hill near Guabito on the Sixaola River. This structure is a faulted anticline with vertical or overturned beds on the seaward (northeast) side and dips of  $40^{\circ}$  to  $45^{\circ}$  on the southwest side. Further inland a smaller structure, the Yorkin anticline shows similar dips. The axis of the fold turns westward up the Talamanca valley. Near Old Harbor in Costa Rica, vertical and steep-angle dips occur in the Gatun formation on the coast, and steeply dipping Oligocene shales are to be seen along the line of the railway between Almirante and the Changuinola River in Panama. Between the Chiriquí Lagoon and the Sixaola River the coastal plain is five or six miles wide with no exposures of consolidated rocks, but a couple of miles beyond the Sixaola in Costa Rica a band of Oligocene, Miocene, and Pliocene rocks appears fronting the sea. The strike gradually changes from N.  $50^{\circ}$  W. to N.  $70^{\circ}$  W. to W., and finally the Miocene rocks disappear under the Pliocene boulder conglomerate in which little or no bedding can be detected. E.-W. strike is also seen in the early Miocene shales which outcrop in a narrow band along the north side of the Talamanca valley, and which also disappear under the boulder conglomerates. There are numerous drag folds, some of which develop locally into small anticlinal and synclinal structures, but the regional structure is arcuate with the steeper side facing northeastward. This convexity is reflected in the course of the continental divide but is obscured by the cover of Pliocene and Pleistocene volcanics; and similar suggestions of arcuate structure on a large scale with minor drag folds can be seen on the Estrella, Banana, and Blanco rivers.

These arcuate folds are cut by transverse faults, some of which may belong to the transisthmian system of central and eastern Panama described above. Others appear to be merely stretch faults incidental to deformation. A study of some of the "smooth sheets" on which the charts of the Hydrographic Office are based was made by the writer (1941). The "smooth sheets" show all the soundings instead of the three to five per cent usually shown on Hydrographic Office charts, and the detailed contouring of the continental shelf reveals some obvious continuations of faults observed on land, and suggests the presence of others so far unmapped. Some of these faults have been indicated on

plates I, II, and III. Those off the mouth of the Sixaola River, Bocas del Toro, and Valiente Point are of particular interest. The shape of the edge of the continental shelf off Cahuita Point as shown on the hydrographic charts is also indicative of faulting on a grand scale, with strike slip shown along the course of the Sixaola River at the end of Senosri ridge. Andesite dikes appear along the course of this fault north of the Río Sixaola.

On the south side of the continental divide, middle Miocene (Gatun) shallow water and terrestrial sandstones with thin beds of lignite appear both east and west of El Barú, the Volcan de Chiriquí. The ejecta of the volcano conceal the structure over an area of 600 or 700 square miles, but at the edges of the volcanics folds appear which presumably continue beneath the cover of tuffs, agglomerates, and flows. The visible folds of the Tertiary sediments roughly parallel the course of the divide and bring the base of the sedimentary series to the surface near David and near Breñon. Whether a continuous fold connects the two is not known but they lie on approximately the same strike. A complex fault network complicates the structure near David. Only the principal faults are shown on plate I. The outcrop of Eocene limestone on the David River about three miles northeast of the town is the first appearance of this formation west of Montijo Bay. It occurs at the intersection of two faults, one striking N. 35° W., the other N. 78° 30' W. The latter brings the basement rocks in contact with the middle Miocene and is apparently the older of the two. The other crosses the Majagua River east of the railroad bridge and for a distance of about three miles is marked by a large andesite dike, which furnishes road metal for the David-Boquete Highway. To the south the fault can be traced to the coast. Its intersection with Río Chiriquí is marked by a sharp hairpin bend of the river about a mile in length. At the limestone outcrop on David River, dark shales, apparently of early Miocene age, are standing on edge striking N. 35° W. on the left bank of the river, while on the right bank, the limestone dips 80° N. and strikes N. 75° W. The indicated stratigraphic displacement is over 3,000 feet, while on the older N. 78° W. fault, the entire Tertiary section below the mid-Miocene is missing, showing a displacement of not less than 5,500 to 6,000 feet. This fault's course westward is marked by a low escarpment in the Pleistocene volcanics and judging by the topography, continues west across Costa Rica to the coast, intersecting Golfo Dulce en route. It is not apparent that this fault is due to the stresses of the arcuate folding. There seems to have been movement on it recently, forming a scarp in Recent gravels west of the Chiriquí Viejo. Another fault on a strike N. 71° E. converges



on the other two near their intersection, and this one is marked by a much sharper escarpment near Concepcion, and by a line of small igneous hills, apparently dikes. The two faults diverge westward and cross the Chiriquí Viejo River about five miles apart. The interval between them includes the crest of a rather tightly folded antiline, with the complete Eocene section showing at the crest and on the north flank, the complete Tertiary sedimentary section up to and including at least a part of the middle Miocene. On the south side of the fold a small section of Oligocene shale is exposed, which is followed to the south by the alluvial flats occupied by the banana farms of the United Fruit Company. The alluvial area is about 12 miles wide and beyond it to the south are the gently arcuate folds of the Burica Peninsula, including marine Pleistocene as well as Tertiary.

The contact of these folded sediments with the alluvium is a fault (F. 1, fig. 4, Structural pattern) which is traceable on land and under the sea for a distance of more than 350 miles. It probably extends much farther. From Puerto Armuelles to and beyond Jicarilla Island, it coincides with a submarine cliff, which off Jicarilla drops 5,400 feet in three miles. On land its course can be plainly traced on air photographs and can be seen at Golfito. At El Cajon, a box canyon on Rio Diquis about four miles above Palmar, Costa Rica, on a fault paralleling it, the basement rocks are thrust to the southwest over the Eocene limestone. This fault plane dips  $60^{\circ}$  to the northeast, suggesting that there is a zone of thrust faulting, of which both faults are a part. Three recently active volcanoes of Costa Rica lie on the fault first mentioned (F. 1, fig. 4) and a fourth is close to it. An oceanic trench, slightly arcuate with convexity to the southwest parallels the coast of Nicaragua and Costa Rica, and numerous earthquakes of shallow depth (less than 60 km.) have epicenters between the trench and the shore. On land a belt of active volcanoes and shocks of intermediate depth (70 to 300 km.) parallel the trench. No gravity anomalies have been measured, but the other features are characteristic of an island arc of the Pacific type, which implies the presence of a thrust fault or zone of thrusting which dips toward the northeast. It is believed that the long fault described above is a part of this zone of thrust faulting, or at least is due to the same stresses. A series of faults striking about N.  $45^{\circ}$  E. are found in Chiriquí Province, the most important passing through Puerto Armuelles, crossing the Burica Peninsula and making a perceptible re-entrant in the continental shelf where it enters the Pacific. These faults intersecting those of NW.-SE. strike, break up the area into a number of fault blocks, which are at present unstable.

For the past 30 years, this general area of southwestern Panama and southeastern Costa Rica has shown the greatest seismic activity in the isthmian region. The climactic year was 1934, and the most destructive shock took place on July 21 of that year at 5:00 a.m. The epicenter is shown on the map as number 5. (Epicenters are located by Gutenberg and Richter (1949) to one fourth of a degree, leaving a margin of error of one eighth of a degree, about  $8\frac{1}{2}$  miles. There is reason to believe that the location given above is incorrect, or one of a simultaneous flock.)

The Chiriquí Land Company, a subsidiary of the United Fruit Company, suffered losses of close to a million dollars, including the destruction of a pier and banana-loading machinery, housing and other structures, and fruit which rotted before new loading devices could be installed. Unfinished houses thrown down were thrown to the southwest. The rails of the railroad which crosses the NE.-SW. fault at right angles were thrown into sigmoidal kinks, but were unbroken, indicating a shortening of the surface from northwest to southeast. Cracks opened on the beach in a NE.-SW. direction and remained open several hours. No tsunami was observed at Puerto Armuelles, but a small one was observed at Punta Burica. Landslips occurred along the line of the N.  $45^{\circ}$  E. fault for a few miles to the southwest but beyond that the region is unsurveyed virgin forest and destruction was not recorded. The fault controls the course of the Rio Guanabaron at several points and a confusion of steep dips is observed in the Pliocene and late Miocene sediments at these places. The fault zone is about 100 feet wide where it crosses the Rio Corotú, with the beds standing at 60 to 90 degrees. In 1949 a well was drilled about 1,300 feet northwest of the fault. This well entered the fault at 7,785 feet indicating a hade of  $10^{\circ}$  to the northwest.

On the Caribbean coast two intersecting systems of faults, one striking NW.-SE. and one NE.-SW., are apparently the product of the same stresses as those of the Pacific side. The edge of the continental shelf is notched at points where it is apparently intersected by some of these faults. Seismic activity, however, is apparently less than on the Pacific side and damage has been comparatively small.

A summary of the structural conditions in the isthmus indicates that in both eastern and western Panama, asymmetric anticlines facing toward the sea are found on both sides of the country. These structures are believed to be, in most cases, cut off by offshore thrust faults dipping toward the land. Most of the structures facing the Caribbean are arcuate and convex to the north. Those facing the Pacific are straighter but may be parts of larger arcuate folds. In

central and eastern Panama, a series of transisthmian faults intersect the folds, and at some of the intersections there is indicated strike slip, the general movement being left lateral. The transisthmian faults strike NE.-SW. in eastern Panama, N.-S. in the region of the Canal Zone, and NW.-SE. in Veraguas and Coel . Similar transisthmian

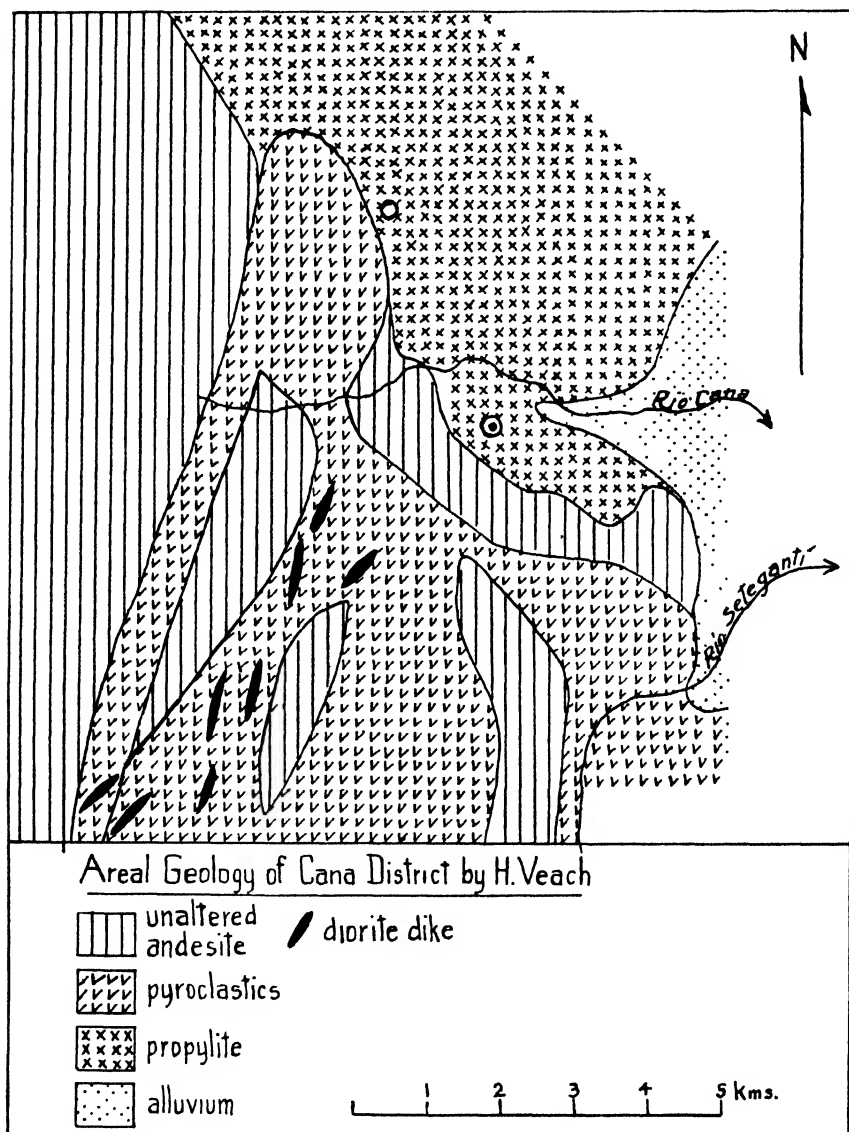


Figure 8. Areal geology of Cana District, by Dr. H. Veach.

faults probably occur in western Panama, but are obscured by Pleistocene and Recent volcanics.

If the offshore thrust faults are projected downward they intersect, giving the isthmus the appearance of a wedge uplifted by pressure from both sides. These stresses have apparently arrived at an isostatic balance in eastern Panama, are slightly active in central Panama, and are vigorously active in western Panama. The sinuous form of the country may be due to local variations in the pressures from the two sides. The squeezing appears to have begun at the east and moved westward. The elevation of the isthmian region which began at the end of early Miocene time apparently had brought all or nearly all the region above sea level by the middle Pliocene. Woodring (1949) has stated the case as follows:

According to vertebrate paleontologists familiar with the Tertiary land mammals of North and South America, the Panama bridge was completed and open to traffic immediately after the end of middle Pliocene time, about 5 million years ago. The first North American migrants, however, reached South America in the late Miocene or early Pliocene, and the earliest South American invaders reached North America in the middle Pliocene. These first arrivals in both continents were small animals and presumably reached their destination by using still separated spans and completed piers as stepping stones.

### ECONOMIC GEOLOGY

Gold mining in Panama goes back to pre-Colombian days and was vigorously continued by the colonists. The metal is to be found in streams heading in the cordillera of the continental divide from one end of the country to the other, as well as in the Azuero Peninsula. Some of the old Spanish mines have been reopened in modern times, but the results in general have been disappointing. Mineralization was shallow, and the Spaniards, despite their lack of modern machinery and technical knowledge, were able to work everything but ores of grades so low as to be unprofitable even now.

Panama's most famous mine was the "Espíritu Santo," near the now-abandoned town of Cana in Darien Province. This mine, one of the Spanish crown's richest revenue producers, was worked from the early part of the seventeenth century to 1727, about one hundred years, when on account of the raids by buccaneers it was declared by the viceroy to be a menace to Spanish rule in the isthmian region and abandoned. It was rediscovered in the latter part of the nineteenth century.

Woakes (1899) has given an account of the mineralization, from which the following excerpt is taken:

The country rock is essentially andesite in an extremely decomposed state.

There are two predominant series of cleavage planes apparent, the first, generally the most marked, running N. 55° W. with a westerly dip, and the second running N. 65° E. with a southerly dip. Roughly speaking, the ore-body appears to have been formed in an irregular quadrilateral, the N. 55° W. cleavages forming the east and west walls while the N. 65° E. form the north and south walls. In adopting this theory, liberal allowance must be made for the variations of bearing, such as would naturally occur in fissures running through such brittle and jointy rock. The sides of the quadrilateral figure are by no means equal or parallel in their entire length. The longer side or base of the figure may be taken as that forming the north wall of the deposit, the shortest is then the opposite or south wall. This gives to the figure the shape of an irregular truncated cone. So far as can be seen, the extreme length of the deposit from east to west is 120 feet while from north to south it is about 90 feet. . . .

By far the greater part of the ore-body is composed of boulders and rock fragments of the adjoining country rock, varying in size from pieces as small as a walnut to masses of many tons weight. They are generally completely angular, but at times are as round as a pebble. In the writer's opinion this roundness is due not to the action of water but rather to a process of decomposition. The rock fragments are completely surrounded by concentric shells of brilliant, crystalline sulphurets and calcite. The order of deposition of these minerals around the matrix is generally iron pyrites, then blende, and then galena, with an outer covering of calcite, in which occur acicular quartz crystals. . . . The gold occurs for the most part in a crystalline form, but often as wires or strings. It is found adhering to the sulphurets, and no doubt the very fine gold is disseminated through them. It is a rule that the greater the percentage of zinc and lead sulphides, in the ore, the richer it is in gold. Three distinct classes of ore have been observed in the lode mass. In the vicinity of the walls, especially the north and south walls of the deposit, the cementing materials of the breccia are chiefly calcite and quartz, while the matrix is softer from more advanced decomposition. Here, therefore, we find low grade ore. Immediately inside this mass, which varies from 15- to 40-feet wide at the different levels, and reckoning from north to south, we find the interstices of the breccia not entirely filled up with the cementing material, an infinity of vugs being left. Here calcite, quartz, and iron pyrites, all more or less crystalline, form the cement. This class of ore assays from one to one and a half ounces of gold per ton, according to the amount of matrix present. To the center and southwest of the lode mass we find the ore very rich in the sulphides of zinc, lead, and iron, all more compact, the vugs being absent. This may be said to be the best class of ore in the mine. Occasional pockets and veins of a soft and friable mixture of all the lode-forming constituents are met, containing free gold in quantity.

Following a bad cave-in in 1911, the mine was abandoned, as production had fallen to an unprofitable level. Production figures for the years 1899 to 1907 are given as follows by Oller (1933):

Produccion por años en libras esterlinas (*production by years in pounds sterling*):

1899-1900 (Feb.) .....	91,671
1901 .....	43,833
1902 .....	41,031
1903 .....	66,970
1904 .....	154,418
1905 .....	52,164
1906 .....	50,070
1907 .....	20,000

Other old Spanish mines have been reopened at Remanse and Mineral in the province of Veraguas, where some production was attained, and near Capira, in the province of Panama, but there are now no active operations.

Mineralization in basic rock practically always is accompanied by propylitization of the andesite. A few slides from specimens taken by the writer near the old adit to the Cana mine were determined as follows by Isotoff:

T 77 —Cana (country rock) Basalt. Intersertal texture-laths of labradorite, grains of augite, etc. Interstitial glass is heavily charged with red iron oxide dust. Phenocrysts of bytownite and augite Chlorite, opal, and carbonate are conspicuous

T 78-T 79—Cana. Propylitized basalt. These sections exhibit various degrees of propylitization of the basalt described under T 77.

T 96 —Pio Nono mine -Darien. Country rock. Augite andesite.

T 97b—Pio Nono near vein Propylitized augite andesite.

T 100 T 104 Sta Lucia mine—Coelé. Propylitized augite andesite

Manganese oxides occur in small quantity in many parts of the country, but mining operations have been profitable only when war preparations caused unusually high prices. The only such operation on a commercial scale was in the upper valley of Rio Boqueron, between Madden Lake and Nombre Dios. The deposit was reported on by Sears (1919), who regarded it as a blanket deposit formed by the alteration of primary ore of unknown character, with subsequent erosion and redeposition in sedimentary rocks which he was unable to date. The region has been intensely faulted and the ore occurs largely as breccia, some of the boulders being 8 to 10 feet in diameter. The work was carried on under the stimulus of the high prices occasioned by World War I and was abandoned after the war.

A manganese deposit of the blanket type occurs near Bahia Honda on the southwest coast of the Soná Peninsula in Veraguas, in a region of pre-upper Eocene igneous rocks. No reports on it are known. Manganese ore also occurs in some quantity near Las Minas in the Azuero Peninsula and in other places.

Copper has never been mined in Panama, but occurs as low-grade sulphide deposits in the province of Veraguas south of the continental divide on the Vigui, Cobre, and Tabasará rivers, and near the head of Rio San Felix. Gold occurs with these copper sulphides and the occurrence of a gold-copper natural alloy has been reported from the region of Remanse, but no reference to it has been found in the literature.

Riddell (1927) reported the existence of a hematite deposit near La Mesa, and unsuccessful attempts have been made at commercial exploitation of magnetite sands on the Caribbean coast near Old Harbor, Costa Rica.

Coal and lignite beds occur at many places in Panama and Costa Rica. They appear in beds of middle Miocene age in the islands and shores of the Chiriquí Lagoon in Bocas del Toro Province and on the upper Changuinola River in the same province, and continue northward in Costa Rica as far as the Reventazon River where their presence is noted by Branson (1928). In central Panama, coal occurs in beds of late Oligocene or early Miocene age in the vicinity of La Mesa, Santiago, Parita, and Macaracas in the provinces of Veraguas, Herrera, and Los Santos; in Panama Province south of Capira, and on the Rio Indio in Colon Province just west of the Canal Zone. Not one of these occurrences has been successfully exploited, although some of them have been prospected.

Oil seepages from the early Miocene occur near Garachiné in Darien Province, Panama, and on Useari Creek and at Uruchico in the Talamanca valley of Costa Rica. At numerous other places oil can be extracted from these shales with chloroform or other solvents. The presence of these seepages long ago became known to Europeans and several European and American companies have made geological investigations, and four companies (Sinclair, Cities Service, Gulf, and Texas) have engaged in drilling operations, with a total of ten wells in Panama, and three in Costa Rica. No production has resulted, although five wells have had shows of oil or gas in the early Miocene, and one found asphaltic residues in beds of middle or late Miocene age. The lack of accumulation in commercial quantity is accounted for by the lack of porous beds in the shale.

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OCCASIONAL PAPERS NO. XXIV  
OF THE CALIFORNIA ACADEMY OF SCIENCES

Issued February 21, 1956

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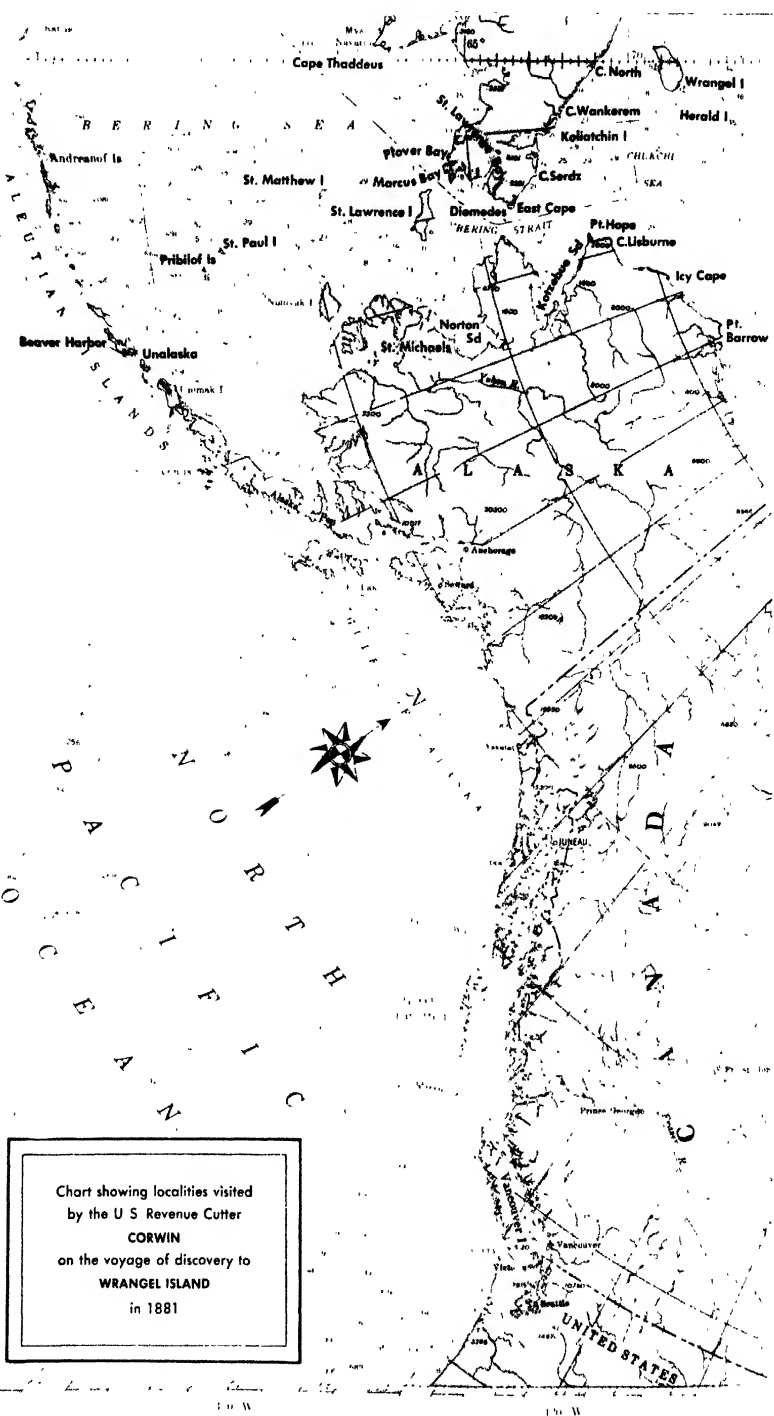
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# The Discovery of Wrangel Island

BY  
SAMUEL L. HOOPER

SAN FRANCISCO  
CALIFORNIA ACADEMY OF SCIENCES

1956



# The Discovery of Wrangel Island

THE DISCOVERER

CAPTAIN CALVIN L. HOOPER, U.S.R.C.S.

1842-1900

A century has passed since that day when a twelve-year-old boy resolutely turned his back on the warmth and security of a New England farm home, determined to seek fame and fortune on the seven seas. The exact manner of his going is not recorded, and certain it is that the path on which he set foot that day led through hardships and dangers, but by following it he gained recognition and fame and the esteem of men.

That boy was Calvin Leighton Hooper, born in Boston on July 7, 1842, the son of Samuel and Mary Leighton Hooper. Calvin's father did not live many years after his son was born. A few years later his widow remarried. Calvin never accepted the change. No doubt jealous of his mother's affections and resentful of what he considered an intruder in the family, he quickly reached the decision to follow the call of the sea.

We know little about him as a boy but it must be clear that Calvin was possessed of great strength of character and determination. Almost without formal education he made himself a very competent navigator and thereby a mathematician. In his mature years he sought his friends among men of education and refinement. His reports to the Congress were outstanding examples of excellent diction and temperate but forceful expression. Dr. David Starr Jordan, beloved chancellor of Stanford University, in writing of the discussion between the United States, Canada, and Great Britain over the operation of the Bering Sea Patrol, which had been authorized by the Paris Tribunal of 1893, an operation which Canada deeply resented, said: "During these delicate and complicated matters, Captain Hooper was always patient, considerate, and just, and his decisions, rendered as a sort of court of appeals at Unalaska, won the respect of all concerned in the acrid controversy."

It is difficult to write objectively of the life of Calvin Hooper, because the boy that we are discussing was to become my father, and any attempts to array the facts in an orderly manner bring a flood of memories that crowd the statistics into the background.

Best of all I remember climbing into his lap during those rare intervals when he was home with us between voyages. I remember the warm comfortable smell of the heavy wool broadcloth of which his suits



were always made; a sense of comfort and security is still associated with that smell. My recollections of him are of unfailing gentleness and affection, but it is recorded that he could be a strict and sometimes stern disciplinarian.

The period from his going to sea as a cabin boy until the time when he got his first mate's papers at the age of twenty-one, the youngest ever recorded, is almost a blank. My impression of it comes from the stories he used to tell as I lay curled up in his arms. These, however, were never in the first person. He would tell of the wonders of the Sargasso Sea, the graveyard of lost ships, or the myth of the Flying Dutchman, or the strange natives of far away places, but never of his own experiences. It was not that he was morose or taciturn; he loved people and was a brilliant conversationalist, but he simply did not like to talk about himself.

At the close of the Civil War competent officers were needed for the United States Revenue Cutter Service and having at that time no academy to draw from, certain young officers were selected from the merchant service. Calvin Hooper was one of the appointees and on June 4, 1866, he was made a third lieutenant by President Andrew Johnson, who had been Vice-President under Lincoln. From this point on his career became a matter of record.

Lieutenant Hooper's first assignment was to the cutter *Lane* at San Francisco. For the next few years he sailed out of that port and cruised mostly in northern waters where he gained the understanding of Arctic conditions that was to serve him so well in later experiences.

The young lieutenant did not spend all his time in the cold of the Arctic, however, and in those intervals when he was in port at San Francisco he became popular at social functions in the bay cities. At one of these gatherings he met a beautiful and talented young lady, Carlotta Elizabeth Hoag, daughter of a well-to-do family in Oakland. Lottie Hoag was a graduate of a popular finishing school where she acquired the graces of those days. She played the pianoforte, she wrote better than average poetry, and had real skill as an artist with oils or water colors. Added to these gracious talents Lottie won fame as a horsewoman, no mean feat in those days when custom demanded that a lady must use the dangerous and awkward side-saddle.

The handsome young officer and the beautiful society girl were immediately attracted to each other, and one evening at the old Cliff House he proposed marriage and was accepted. Unfortunately for the course of true love, just at this time Calvin, who was now a first lieutenant, was ordered to the cutter *Pescenden* at Detroit. The move came suddenly and arrangements could not be completed for their wedding

before his departure. Lottie Hoag, however, proved her fitness to be the bride of a sea captain, she followed him by train to Chicago and they were married in the old Sherman House in 1872. Such a trip by a young girl alone was almost unheard of in those days.

My father and mother were an outstanding couple in appearance, and in my home life I never detected the slightest hint of quarreling or unkindness between them. There now followed a period of about



Figure 1. Captain Calvin Leighton Hooper, U.S.R.C.S.

eight years that was typical in the life of a young officer and his family. In that time they were stationed at Detroit, Philadelphia, Boston, Erie, Baltimore, and Port Townsend, Washington. During this period three children were born, a son at Baltimore, a daughter at Erie, and another daughter at Port Townsend. Some years later another son was born at Oakland, California.

In 1880 Captain Hooper was placed in command of the cutter *Corwin* at San Francisco. This was like returning home again, which in fact it was for Lottie. Here for the first time they could begin the establishment of a real home and in the *Corwin* Captain Hooper began to shape the career which was to make him famous.

In 1880 he took the *Corwin* into the far north and found that the natives on Saint Lawrence Island and some of the other islands nearby had perished by hundreds during the previous winter, whole families and even the inhabitants of entire villages were found dead in their huts. Investigation proved that the disaster had been due to the severity of the winter which had prevented the usual hunting during the time that game was plentiful, and the deaths had been due to starvation. Captain Hooper's report to Congress on these conditions established him as a competent and able Arctic hand.

In 1881 the New York *Herald* was demanding that efforts be made to locate a polar expedition under the command of George Washington De Long, U.S.N., an experienced and capable officer, who was endeavoring to reach the North Pole by forcing his way into the Arctic ice and counting on the drift to carry him close to the Pole. The De Long party had been out over two years and no word had been received from them for a long time. As a result of the hue and cry that was raised, two relief parties were organized. The Navy sent Lieutenant Berry in the *Rogers* and the Revenue Cutter Service instructed Captain Hooper of the *Corwin* to make search for De Long's ship, the *Jeanette*, along with his usual duties as a unit of the Bering Sea Patrol.

Captain Hooper's sailing instructions, his preparations, and the details of the voyage which led to the discovery of new land in the Arctic and its claiming for the United States are all set forth in the following account.

Upon his return from this voyage in 1881 Captain Hooper found himself famous. Ships reaching San Francisco after contacting the whaling fleet brought reports of the discovery of Wrangel and of the voyage of the *Corwin*. These reports found their way into the press and a pamphlet describing the voyage was published by the Geographic Society of the Pacific. John Muir, the great geologist, who

was a member of the *Corwin* party to study the glaciation of the Arctic, wrote letters home and these were eagerly sought after by the then current publications. The result was that even before the return of the *Corwin* to her home port the fame of the voyage had spread.

As a result of this voyage Captain Hooper was now permanently assigned to the Bering Sea Patrol, he served in command of both the *Rush* and the *Corwin* at various times. For two years during this period the Patrol was handled by the Navy, and Captain Hooper served under the famous Admiral Robly D. (Fighting Bob) Evans. The two became fast friends. In his autobiography, *The Log of a Sailor*, in describing an assignment given to the *Corwin*, Fighting Bob wrote, "The captain was an able and fearless man and I knew he would carry out my orders . . . Captain Hooper of the *Corwin* carried out my instructions carefully and the result was a happy one." After the Navy turned the operation back to the Treasury Department, Captain Hooper himself was put in full command of the Bering Sea Patrol and was extended the thanks of the Department for co-ordinating its activities. During this period also Captain Hooper was given the responsibility of the office of superintendent of construction and repairs for the Revenue Cutter Service on the Pacific Coast. This was welcome as it gave him full activity in those months that had to elapse between Arctic voyages.

Captain and Mrs. Hooper had long planned on a home where he could settle when his days at sea were over, and in 1896 they purchased a spacious and beautiful home at 202 Santa Rosa Avenue in the Linda Vista District of Oakland. In the fall of that year Captain Hooper requested to be relieved of active sea duty in order to devote his time to his shore responsibilities. This was granted and he was assigned offices in the old Appraisers Building in San Francisco. It looked now as though he might enjoy his home and family in peace. Such, however, was not to be.

In 1898 war was declared against Spain and immediately Captain Hooper requested active duty again. The Secretary of the Treasury wired him that for the moment he was needed where he was, but thanked him for the prompt offer. Just at this time a new cutter was launched in New York and was named, as was and is the custom, after a Secretary of the Treasury. It was Hugh McCulloch whose signature appeared along with that of the President on Captain Hooper's first commission, and it was his name which was given to the new cutter.

The *McCulloch* was launched just at the outbreak of the war and

was placed under the command of Captain Daniel B. Hodgsdon with orders to report to Admiral Dewey's Asiatic Squadron. These orders were carried out and the *McCulloch* accompanied Dewey's fleet to Manila and took an active part in the destruction of the Spanish fleet on May 1, 1898. In June of that year Captain Hodgsdon was relieved of command and ordered home, he had passed the retirement age and his health had suffered in the service in the tropics.

Captain Hooper was ordered to leave San Francisco on the transport taking the troops to the Philippines and to take command of the *McCulloch* on arrival. He reached Manila on July 13, 1898, and took over his new duties at once. On August 16 of that year word was received of the cessation of hostilities and shortly thereafter Captain Hooper was ordered to carry the official news of the victory to San Francisco and to "show the flag" in Hong Kong and Yokohama en route.

At the conclusion of the voyage he retained command of the *McCulloch* until failing health forced a change. His hopes and plans for a quiet home life were not to be realized. The hard duty in the tropics had taken its toll. After a severe illness he died at his home on April 7, 1900.

Again memories flood my thoughts. I remember well the solemn services at the crowded Masonic Hall and the slow ride out Broadway in Oakland, made even slower than was usual even in those days by the fact that the casket went ahead mounted on a gun carriage and on either side marched an honor guard from the *McCulloch*. As we passed the old Grant School at Twenty-ninth and Broadway I could not refrain from peeking out and seeing all my schoolmates standing spellbound at the spectacle.

Finally the casket was lowered into a grave on a sunny California hillside, a final salute was fired, and taps were sounded for the little boy who had so resolutely turned his back on comfort and security in order to seek fame and fortune.

### THE VOYAGE OF DISCOVERY

Surrounded by polar ice and shrouded in the chill mists of the Arctic, lying close to the forbidding coasts of Siberia, is desolate Wrangel Island, a bleak and barren region claimed by the Soviets but actually discovered in the name of the United States by an American over seventy years ago.

Outside of the Soviet Union geographers and historians agree that an American, Captain Calvin L. Hooper, commanding the U.S. revenue cutter *Corwin*, was the first to set foot on this Arctic wasteland

and to claim it in the name of his country. The United States has never seriously disputed Russia's sovereignty over it, probably because at the time of its discovery it was so inaccessible and desolate that it seemed of little or no value. Who in those days would have dared to dream of transpolar aviation?

The story of Captain Hooper's discovery of Wrangel opened early in the afternoon of Wednesday, May 4, 1881, when the *Corwin*, under his command, passed through the narrow channel of the Golden Gate outward bound on a voyage that was to cover well over fifteen thousand miles of cruising in the then little-known waters of the far north. She was about to engage in a relentless warfare with those implacable foes of Arctic navigation, gales, ice, and fog, which would have daunted any less-hardy ships or men. However, on that pleasant spring day, with the Marin County hills blanketed in green, patched here and there with great masses of gold where clusters of California poppies grew in profusion, all of this Arctic adventure was hidden in the future. It must have been a splendid sight as the *Corwin*, her colors snapping in the breeze, escorted by the cutters *Rush* and *Hartley*, and the yachts of the San Francisco Yacht Club under Commodore Harri-



Figure 2. The *Corwin* outward bound from San Francisco

son, passed beneath the grim guns of Fort Scott and dipped her bow to the long swell of the Pacific.

Captain Hooper's objectives in undertaking this difficult and hazardous journey into the frozen North were threefold:

First, was the regular summer assignment of the *Corwin* as a unit of the Bering Sea Patrol. The duties called for under this assignment were of such a nature as to require extreme delicacy in handling, if serious international complications were to be avoided.

The clearest understanding of these unusual operations may be obtained from an account written a few years later by Professor David Starr Jordan, widely known educator and beloved chancellor of Stanford University, in his autobiography, *Days of a Man*. In recounting his own experiences in Alaska he writes, "Captain C. L. Hooper, a brave and loyal officer, was then commander of the Bering Sea Patrol composed of three revenue cutters, *Rush*, *Perry*, and *Corwin*. The duty of this little flotilla was to see that the Canadian sealing fleet broke none of the provisions of the Paris Tribunal . . . To this end they were directed by our government to overhaul schooners at sea and open up the barrels of salted skins to find out if they bore evidence of having been put down before the end of the closed season. Such inspections, carried out hastily in rough weather, were irksome to both parties, and the unavoidable scattering of the sealskins about the deck naturally made the operation doubly distasteful to the Canadians. Furthermore, I believe the whole operation to have been contrary to international law." Professor Jordan then proceeds to emphasize the patience, the consideration, and the justness which Captain Hooper always demonstrated while acting in the difficult role of enforcement agent in carrying out these complex and delicate diplomatic assignments.

The second objective of the voyage was a direct result of the report of the cruise of the previous year. Captain Hooper had taken the *Corwin* into the far north in 1880 and had brought back reports of starvation and death among the natives of Saint Lawrence Island due to a very severe winter. His instructions for the cruise of 1881, therefore, included these specific orders, ". . . you will in your cruise touch at such places on the mainland or islands where there are settlements of natives and examine into and report upon their condition."

The third and most important objective, which necessitated a penetration into the Arctic ice far deeper than the *Corwin* had ever before attempted and which required that a landing be effected on an unknown land where none had ever set foot, requires a word of explanation.

For many years legends had come down from the Chukcheis living along the shore of the north coast of Siberia, of a land mass lying far to the north amidst the polar ice. In 1820 Lieutenant Ferdinand Wrangel of the Tsarist navy, made the first of several attempts to reach it; he was later to gain fame as admiral and baron and finally to become governor of Alaska under the Tsars, but it is a matter of record that he never saw any land located where we now know Wrangel Island to be.

The first actual sight of the mysterious land was made by Captain Henry Kellett of the H.M.S. *Herald*. In the summer of 1849, while conducting a search for the Sir John Franklin Expedition which had been lost in the Arctic, Captain Kellett discovered an island lying north of the Asiatic continent. He landed and claimed it in the name of Her Britannic Majesty, Queen Victoria, and he named it Herald Island in honor of his ship. From the summit of its highest peak (1200 feet) the tops of mountains could plainly be seen bearing due west. Kellett surmised this to be the legendary land and he named it Kellett's Land. Although Kellett only saw it from a great distance and never got any nearer than the top of Herald Island, his name is still used on some of the British Admiralty charts.

Kellett, of course, proved the existence of land in that part of the Arctic Ocean, but the various ideas regarding its size and shape differed widely. Many supposed it to be an Arctic continent which, starting at a point less than two hundred miles from the Siberian mainland, extended far to the north, possibly even to the Polar regions. Its eastern shoreline was assumed to run roughly north and south. This conception of an Arctic continent was so generally accepted that the land became known as Wrangel Land, in honor of Baron Wrangel who was among the first to be identified with the search for the phantom continent.

While much of this was pure guesswork and had no foundation in fact, the supposed existence of this land barrier exerted a tremendous influence on the thoughts and plans of those interested in Arctic exploration. Outstanding among these at that time was Lieutenant Commander George Washington De Long, U.S.N., who, with the backing of the New York *Herald* had organized an expedition to attempt to reach the North Pole, which expedition sailed from San Francisco, July 8, 1879. It was Commander De Long's plan to touch at Herald Island, and after leaving markers there, to proceed along the coast of Wrangel Land leaving records about every twenty-five miles. He planned to steer boldly into the polar ice pack and, hoped to be carried by the current to the area of the Pole if not directly



over it. He presumed that the supposed Arctic continent would bar or direct his drift.

Such planning required high courage and the fact that he put it into effect exactly as contemplated speaks well for Commander De Long's determination and bravery. The story of the fateful voyage of his ship, the *Jeannette*, and the heroic struggles of the little handful of those who survived, has been splendidly told by Commander, now Captain, Edward Ellsberg in his book, *Hell on Ice*. We know now that De Long in the *Jeannette* never reached either Herald or Wrangel Island and that the Arctic current carried him directly across the area where he supposed the "continent" to exist and far to the north and west. The *Jeannette* was crushed in the ice and sank on June 11, 1881. While the *Corwin* and others were searching for signs of her, the survivors of that ill-fated expedition were making their way over frozen seas in an attempt to reach the north coast of Siberia. A few gained the Siberian shore and with the aid of friendly natives finally reached Alaska. Commander De Long, and a small group of his crew, reached the delta of the Lena River in northern Siberia only to lose their lives there after terrible hardships.

By 1881 the newspapers, led by the New York *Herald*, were demanding that rescue expeditions be sent out to search for the De Long party, now unheard from for nearly two years. Two such expeditions were undertaken, one by the Navy under Lieutenant Berry in command of the *Rodgers* and the second by the revenue cutter *Corwin* commanded by Captain Hooper, who was instructed to make such a search in addition to his usual assignment. His sailing orders read in part: "No information having been received concerning the whalers *Mount Wallaston* and *Vigilant*, you will bear in mind the instructions for your cruise of last year, and it is hoped that you may bring back some tidings of the missing vessels. You will also make careful inquiry in the Arctic regarding the progress and whereabouts of the steamer *Jeannette*, engaged in Arctic explorations under the command of Lieutenant Commander De Long, U. S. N., and will if practicable, communicate with and extend any needed assistance to that vessel."

Aboard the *Corwin* on this voyage were two well-known scientists whose work added much to its importance. Professor John Muir, who was to identify the great Alaskan glacier which now bears his name, and Dr. E. W. Nelson, who joined the ship at Saint Michaels and was later to become chief of the U. S. Biological Survey. It was Professor Muir's desire to study the glaciation of the Arctic and Dr. Nelson's to study and report on its plant and animal life.

No discussion of the personnel of the party would be complete, however, without a word about Captain Hooper himself.

Born in Boston in 1842, he was thirty-nine years old at the time of this voyage. Like so many boys from New England seaports, salt water had gotten into his veins at an early age. When only twenty-one he was first mate on one of the famous American clipper ships, and early photographs show him wearing a very formidable looking set of dundrearies in order to hide his age, or lack of it.

In 1866, just at the close of the Civil War, young Calvin Hooper was commissioned a third lieutenant in the Revenue Cutter Service, now the United States Coast Guard. With that was begun a career which spanned thirty-four years of devoted and loyal service to his country. This was climaxed by his command of the revenue cutter *McCulloch* operating as a unit of Admiral Dewey's fleet in the Spanish American War.

In addition to the glowing reference to his tact and judgment accorded by Dr. Jordan in his book, we have a splendid tribute to his character and ability in the published autobiography of Admiral "Fighting Bob" Evans, *A Sailor's Log*. He describes a dangerous and critical operation which he entrusted to Captain Hooper and goes on to comment on the ability and fearlessness of the captain. Admiral Evans found that in every situation Captain Hooper could be relied upon to carry out his instructions carefully and intelligently and with happy results.

The captain's report to Congress of the voyage of 1881 was published as Senate Executive Document No. 204. Also Professor Muir wrote a splendid account of the same trip in his book, *The Cruise of the Corwin*. These two complete the published record of the journey.

In addition to these sources, much of the information regarding the details of the voyage comes from an hitherto unpublished personal diary meticulously maintained by Captain Hooper. Each day in the privacy of his cabin, he carefully began with a description of the weather and often a statement of their position, then followed a brief statement of the day's events. Sometimes the writing was hardly decipherable as the little vessel struggled against heavy seas, often it must have been written by the light of the ship's lantern as they rode out a gale in the lee of an Arctic island. This personal diary must not be confused with the ship's log, which, of course, was carefully kept and was the basis of the report to Congress. This record was truly personal, as for example when he writes on May 4, the day of departure:

May 4, 1881. Weather fine, said goodbye and God bless you to my darlings and

went to the vessel made all ready and started at 1:00 p.m., accompanied by the cutters "Rush" and "Hartley" and the yachts. Got well clear of the land before dark. Am feeling blue enough about leaving home

Or this choice entry of March 8, 1881, during the preparations for the cruise.

Weather fine Stayed on board all day Lieut. B. called on board to see me. Received him as he deserves, would like to kick him over the side.

As the *Corwin* headed into the north Pacific her log shows fair winds and a following sea, and aided by these she made splendid time. On May 7, three days out, the captain wrote:

We are doing well. At noon we were as far along as we were at noon on the fourth day out last year.

However, the favorable weather was not to continue. On May 13, the wind was rising and on the following day the entry was:

Still blowing from the southward Thick and raining Bar very low (29.40) Heavy sea, carrying sail and steam, hard in hopes of getting in tomorrow night.

May 15, 1881 Wind blowing a gale N.W. with a heavy head sea Within fifty miles of Unalga Pass at meridian If this gale had not come on we would have reached Unalaska today and made the passage in eleven days

The state of the weather forced the *Corwin* to seek shelter in Beaver Harbor which they reached "barely escaping the loss of our boats." After the storm had blown itself out they reached Unalaska on May 17 and immediately hauled the *Corwin* on the beach to repair the oak sheathing which had been torn away by the force of the waves. After the repairs were completed they took on coal and water and nine months' extra provisions which they arranged to return to the Alaska Commercial Company without loss to the government if they were not needed on the voyage.

The *Corwin* cleared from Unalaska on May 22 and shaped a course for the Pribilof Group where the great fur-seal rookeries are located. Saint George Island was reached in a fog so thick that they found their way only by the great flocks of sea birds that filled the air. No attempt was made to land here but they proceeded on to Saint Paul Island where a landing was effected.

It was too early for the main body of the seal herds, only a few

old bulls had arrived so far to take possession of the ground upon which, on the arrival of the cows, they would establish their harems. Only a short stop was intended here and as soon as they had rigged a "crow's nest" at the masthead and had secured their icebreaker in position and made other necessary preparations a course was laid for Saint Matthew Island. The entry reads:

May 23 At 8:00 p.m. got underway, shaped course for St. Matthews to have a bear hunt.

May 24 - Wind S.W. and cloudy steering for St. Lawrence Island. At 1:00 p.m. made the ice and hauled off to the westward and shaped a course for Cape Thaddeus, Siberia. Will have to deter the bear hunt.

Having encountered the ice pack as far south as latitude  $58^{\circ} 42'$ , the only course open to the *Corwin* was to work her way back and forth seeking to penetrate the pack where possible and to follow the ice as it receded to its summer limits. In the official report the captain stated, "Remembering our rough experience of last year in trying to get north along the east side of Bering Sea, we determined to keep, if possible, to the westward of the pack, and, if necessary, follow the land water along the Siberian coast, proceeding no faster than the ice should leave the shore. According to my experience, the west shore is navigable much earlier than the east."

Accordingly they steered for the Siberian coast, using both sail and steam and keeping a sharp lookout for the whaling fleet which could be expected heading for Bering Strait. They worked their way north and west keeping the ice pack always in sight on their starboard beam and making slow headway through the loose drift ice. Only logging about five knots against a strong current and an east wind of gale force and in a blinding snowstorm, it was not until May 28 that they reached a native settlement on the northeast end of Saint Lawrence Island.

The arrival of the *Corwin* was hailed with joy by the natives who came aboard in large numbers. It had been noted that an American flag was flying from one of the native huts. It turned out to be the property of the schooner *Lolita* which had been wrecked on the north coast of the island in the fall of 1880 while on her way to San Francisco under seizure by the *Corwin* for a violation of law in Alaskan waters.

Some trading was done with the natives but they had little of value and could furnish no authentic information about any of the vessels for which the *Corwin* was searching. After a short stay a course was

laid for Plover Bay on the Siberian coast, taking along two families of natives who were anxious to reach the mainland.

Finding Plover Bay icebound they headed for Marcus Bay a few miles farther south and on the way there they spoke the whaling bark *Rainbow*, Captain Lapham, and delivered to him the mail for the whaling fleet, which the *Corwin* had brought from San Francisco.

Captain Lapham had learned from the natives that a party of seal hunters had discovered a wreck near Cape Serdz which was believed to be one of the missing whalers. Considering this report to be of sufficient importance, and because it would still be some weeks before the *Corwin* could make her way north along the coast, Captain Hooper determined to put a sledge party ashore to attempt to learn the facts.

It was proposed that this party proceed along the Siberian coast, contacting the natives and making thorough inquiry in order to determine, if possible, the exact location of the wreck and at the same time to secure any information regarding the *Jeannette*.

Steps were immediately taken. At Marcus Bay a native known as "Chuckehi Joe" was engaged as a dog-team driver and guide and one team of fine dogs was secured. No other supplies were available so a course was laid for Saint Lawrence Bay farther north. The bay was choked with ice but an anchorage was found off a small settlement on the south side of the bay. No dogs were to be had either for purchase or hire.

However, when questioned about the wrecks, one old native became a self-appointed spokesman and after asking for a glass of water he waxed quite eloquent. With a wealth of appropriate gestures he related in detail the position of the wrecks and described the corpses lying around on the ice, one of which he readily identified as that of Captain Nye of the *Vigilant*. Captain Hooper says, "It would be difficult for anyone unacquainted with Chuckehi character to realize that most of this was manufactured on the spot for the sake of the reward which was expected to follow." After making allowances in full for native imagination there seemed to be some foundation for the story and the captain was more determined than ever to proceed with the sledge party.

Leaving Saint Lawrence Bay the *Corwin* headed for the Diomedes, a pair of small islands lying directly in the middle of Bering Strait. The international date line which also marks the boundary between Russia and the United States passes between these two islands, with the result that when it is Saturday on Little Diomedé, which is United States territory, it is Sunday on Big Diomedé, which is Russian territory although they are only three miles apart and each can be plainly

seen from the other when the weather is clear. The entry in the captain's private notes for the day reads:

Monday, May 30, 1881. Weather stormy and disagreeable. Snowing hard all day—anchored at Diomedé, bought boots, fur clothing and . . . also bought 19 dogs and two dogsleds. Paid one sack of flour each. Left in the evening for Cape Serdz to land the shore party.

Cape Serdz Kamen, to give it the full name on current charts, lies on the northern coast of Siberia about one hundred miles west of East Cape, which is the most easterly point of the Asiatic continent. This promised to be a difficult objective to reach but on the way there they spoke the bark *Helen War*, Captain Beaudry, who reported the ice well broken to the north. As the *Corwin* followed the coast they encountered a rim of ice ranging from five to thirty-five feet high and extending from two to ten miles offshore. They followed this shore ice westward with the "blink" of the pack always in sight to the north although the pack itself was below the horizon. An ice blink is simply the light reflected into the sky by the sun's rays shining on an ice field and it often serves to locate the ice floes before they are actually in sight.

The next day, June 1, the *Corwin* encountered solid-pack ice showing that the end of the open lead had been reached. Although the captain was anxious to put the sledge party ashore he did not feel it prudent to embark them on the ice until the land could be plainly seen.

While waiting for a change in the weather, which was blowing a moderate gale, or a change in ice conditions which would enable them to approach nearer the land, the *Corwin* cruised under sail in the open lead. Shortly after midnight the ice closed in on them and it became necessary to use the engines to work out of it. In endeavoring to free themselves the rudder was broken and unshipped, every pulley being carried away. The official report reads, "The situation was anything but pleasant, caught in the end of a rapidly closing lead, 120 miles from open water in a howling gale and driving snowstorm and without a rudder. It at first appeared as if the destruction of the vessel was inevitable."

Describing the experience in *The Cruise of the Corwin*, Professor Muir writes, "The situation was sufficiently grave and exciting, dark weather, the wind from the north and freshening every minute, and the vast polar pack pushing steadily shoreward. It was a bleak stormy morning with a close sweeping fall of snow, that encumbered the deck and ropes and nearly blinded anyone compelled to look to windward. Our twenty-five dogs made an effective addition to the general uproar, howling as only Eskimo dogs can howl. They were in the way, of

course, and were heartily kicked hither and thither. The necessary orders were promptly given and obeyed. Soon the broken rudder was secured on deck, four long spars were nailed and lashed firmly together, fastened astern and weighted to keep them in place at the right depth in the water. This made a capital jury rudder. It was worked by ropes attached on either side and to the steam windlass. The whole was brought into complete working order in a few hours, nearly everybody rendering service, notwithstanding the blinding snowstorm and peril, as if jury-rudder making under just these circumstances were an every-day employment."

When the jury rig was all ready the bell was rung to go ahead and the captain waited with some anxiety to test the *Corwin's* response to the makeshift rudder. To everyone's great relief it was found to answer admirably and the vessel controlled without difficulty.

The captain now planned to work his ship toward the open end of the lead as there was danger that the northerly wind would close it entirely, and to be caught between the pack and the shore ice would mean certain destruction. In the afternoon the snow let up for a brief period and they clearly saw Koliatchin Island which lies very close to the mainland, and having determined from the native guide that the condition of the ice was "pretty good," preparations were made to land the shore party. They were embarked on the ice and a party of native seal hunters rendered them invaluable aid in getting their heavily loaded sleds over the rough spots.

The little party struggling over the hummocks and pressure ridges of the shore ice consisted of First Lieutenant Herring, Third Lieutenant Reynolds, Coxswain Gessler, and two natives. They had twenty-five dogs, four sleds, and one skin boat, together with provisions, arms, ammunition, and the necessary navigation instruments. They also carried a supply of trade goods as gifts and rewards for the natives they expected to encounter.

Instructions were given Lieutenant Herring to proceed along the coast as far as practicable, communicating with the natives at each settlement and if possible to find the parties who were said to have discovered the wreck and to gather all facts in connection with it that could in any way throw light on the fate of the missing whalers or the *Jeanette*. As regards rejoining the *Corwin*, when this task was completed they were instructed as follows: "The *Corwin* will be at Tapkan June 15, June 20, and July 15. If you do not meet the vessel at any of these dates proceed to East Cape, leave letters at all settlements stopped at both going and coming. In case the vessel does not reach East Cape by the fifteenth of August, go to Plover Bay; on the

way stop at Saint Lawrence Bay and leave letters with the natives to be put on board whaling vessels or to be delivered to the *Corwin*, giving information of date of passing, etc. Inform all natives met with of the object of your visit, and request them to assist any parties of white men that may at any time appear on their coast, and assure them that any services rendered will be well rewarded."

Little is known today of the previous ice experience of Lieutenants Herring and Reynolds, but it took plenty of courage to start out over the rough ice on a journey of over two hundred miles in a thoroughly inhospitable land. The feelings of the little party may well be imagined as, looking back over the pressure ridges of the shore ice, they saw the masts of the *Corwin* gradually disappear as she worked her way to clear water.

As soon as the sledge party was safe ashore, the *Corwin* made haste to escape from the rapidly closing lead. When she reached open water, expecting to head for Plover Bay to effect repairs, she found Bering Strait to be filled with ice, probably driven in from the Bering Sea by the same storm that had set the pack on shore. The route to Plover Bay being closed, a course was shaped for Saint Lawrence Island which was reached at midnight and an anchorage was found near the northeast point.

The following day was spent in searching for the wreck of the *Lolita* which was known to be on the north shore of the island. The captain hoped to be able to use her rudder pintles in making the needed repairs to their rudder. The wreck was found but her pintles were already broken, however, they did secure some material which was useful to them when the opportunity came finally to complete the repairs.

The next day, June 10, the wind was still southwest, the weather very thick and snowing hard. The *Corwin* was lying close in under the shelter of the towering cliffs of the island. Because of the uncertainty of the weather and the somewhat precarious situation which they were in, a sharp lookout was maintained, the fires heavily banked so that steam could be gotten up quickly, and chains on the windlass made ready to get away on short notice. This alertness was well repaid.

About 4:00 a.m. the lookout reported a large field of ice moving toward the ship; this proved to extend as far as they could discern in either direction and was high enough to endanger the boats hanging in the davits. This probably represented fifteen to twenty feet of ice above the surface of the water and a total depth of sixty to eighty feet and this tremendous mass was moving inexorably toward the



shore, with the *Corwin* anchored in the rapidly closing area of open water between.

The official report reads, "It came in like a solid wall, drifting directly towards the shore and extended each way as far as we could see and looming up through the blinding snowstorm, growing higher and more distinct as it came nearer until it seemed all ready to fall on and crush us. On the other side the perpendicular cliffs of the island seemed directly overhead and the discordant notes of the sea birds perched on the rocks were becoming more and more distinct each moment as the narrow belt of water between the boulder-lined shore and the incoming wall of ice grew gradually less. To be caught under such circumstances meant certain destruction, and but one way of escape seemed possible, namely, to force the vessel into the floe and take the chances of a nip in the ice, which was sure to follow."

Such a floe always presents some cracks or leads and the captain now proposed to force the ship into one of these in hopes of entering far enough so that when the ice crushed against the shore she would be out of the pressure area. This was certainly not a comfortable spot to be in and to make matters worse in attempting to find such a lead in which to escape, their jury rudder was broken and had to be triced up under the stern to prevent it from fouling the propeller. Finally by backing full speed the *Corwin* was forced several lengths into the ice.

Then followed a period of tense anxiety on the part of everyone on board. Would the pressure of the oncoming ice continue until they were crushed against the shore? Would the offshore movement of the floe close the lead into which the *Corwin* had been forced? No action on the part of the crew of the *Corwin* could in any way alter the situation, but they at once prepared to take advantage of any opportunity for escape that might present itself, by making temporary repairs to their rudder.

After several anxious hours the lookout from the masthead reported that the ice was again setting offshore and soon open water appeared once more between the pack and the land. Some fortunate change in wind or current had reversed the movement of the floe and the *Corwin* was quick to take advantage of the situation, to free herself from danger.

A course was shaped for Plover Bay but because of loose drift ice in the strait it was a slow and hazardous journey. On June 13 they anchored in the bay and proceeded to coal ship from an open coal mine on the Siberian shore. This was not a coal mine in the commercial sense, but simply a surface deposit of coal so much exposed that it was possible to dig it and load it onto sleds without the need of any

equipment except picks and shovels. It was well known to all Arctic vessels and was available to any who needed it. The report says, "On the morning of the thirteenth all hands were turned to coaling ship. We had constructed two large sleds which would carry about half a ton each, and dividing the crew into three parts, one was put at the coal pile to fill coal into sacks, while the other two were drawing it to the ship on the sleds. The distance from the coal pile to the vessel in a direct line was about a mile and a half, and the rapidly melting ice was very soft on the surface and covered with deep pools of water. Notwithstanding the long distance and the unfavorable conditions, with the assistance of the natives we succeeded in taking on about nine tons a day."

Late in the afternoon the whaling bark *Thomas Pope*, Captain M. V. B. Milliard, came in and made fast to the ice in order to take on fresh water and fuel for her galley ranges. Some of the whalers were away from their ports two years or more and the matter of getting such supplies was a serious one. Coaling continued until late on the fourteenth when a movement of the ice indicated that it was breaking up. The *Corwin* took the *Thomas Pope* in tow and made her way through broken ice to clear water.

The weather clearing somewhat, the *Corwin* now shaped a course for Norton Sound directly across Bering Sea on the Alaskan side. The move from the Siberian mainland to Alaska brought about a remarkable change. The short Alaskan summer was at its height, the weather was beautiful, the fields were bright with wild flowers, and the abrupt contrast between these beauties and the gales and fogs they had been experiencing seemed almost miraculous.

Several days were required for repairs to the rudder and boilers and then the *Corwin* sailed again for Saint Lawrence Island and from there to Plover Bay to complete the coaling which had been interrupted by the breaking up of the ice. Full bunkers were needed because ahead of them lay a long journey with no further supplies available for some time. Taking on board fifty-four additional tons of coal they shaped a course for Tapkan to learn whether the sledge party had reached there. The *Corwin* had been forced to miss the first two of the assigned dates for meeting the shore party and there was anxiety to make contact as soon as possible.

As the *Corwin* nudged and buffeted her way through heavy drift ice toward Tapkan village on Koliatchin Island, the little group in her pilot house were deeply concerned. Had the shore party arrived? Were they all right? Had they suffered any accidents? These questions filled their thoughts.

Finally, through the glasses they made out something moving on top of one of the native huts. It soon proved to be an American flag and they wondered if it indicated the presence of the shore party. They recalled the flag flying on Saint Lawrence Island which had been taken from the wreck of the *Lolita* and were not sure. Soon, however, they were able to identify Lieutenant Herring and the rest of the party as they hastened preparations for joining the ship over the ice. Word was now passed that the shore party were safe and waiting, and immediately all was excitement on board. Had they found the *Jeannette*? Had they learned anything definite about the missing whalers? These and hundreds of other questions awaited an answer. The sledge party in their eagerness to return to the *Corwin* were now making their way out over the ice, and two small boats were at once dispatched to pick them up. The swell of the sea was keeping the ice in so much motion that it was only with greatest difficulty and considerable danger to all concerned that the operation was successfully completed.

All the men were warmly welcomed on board, including the Tapkan dog driver, who came aboard to receive his pay. By the time this was attended to the wind had increased so that he could not be put on shore. On being asked if he could get back from East Cape he assured the captain that he could walk back in only three days, so the *Corwin* proceeded toward the strait.

The sledge party under Lieutenant Herring had reached Cape Wankarem, about one hundred miles west along the Siberian coast. They had found the actual discoverers of the wreck and had secured a number of articles from the lost vessel, for which they amply reimbursed the natives. From the markings on some of the items, as well as from the description by the natives of a wreck having a pair of deer antlers made fast to the bowsprit, the wreck was established as that of the *Vigilant*. The party also received definite word that the *Jeannette* had contacted some natives in the fall of 1879, and while this was already known, having been received from the whalers, it showed that the statements of the natives could sometimes be depended on. The results obtained by the shore party had been most successful. In return for hardships and difficulties undergone, they had fully established some of the facts which were the objectives of the voyage.

With her full crew again on board the *Corwin* was now free to make further search to the north, and the strait being free of ice, they headed for the Diomedes and then touched at Saint Lawrence Island and from there crossed over to Norton Sound on the Alaskan shore. Everywhere they went native settlements were contacted wherever

they were known to exist and at the same time a check was made on any strange vessels that the *Corwin* encountered.

After anchoring a few days at Saint Michaels, and taking on further supplies, a course was laid for Kotzebue Sound on the north side of the Seward Peninsula and they finally worked their way around Point Hope where they had to anchor and ride out a full gale that lasted four days. July 22 found the *Corwin* again under steam and sail and headed north and east along the top of Alaska hoping to reach Point Barrow where there was a large settlement. At Icy Cape, however, the pack was encountered and further progress in that direction was out of the question for an indefinite period, since the ice showed no signs of breaking up.

Under these conditions Captain Hooper decided to make a determined attempt to accomplish his principal objective, to land on Herald and Wrangel islands in order to determine whether the *Jeannette* had touched there and left a record. In putting this plan into effect the *Corwin* was, first of all, headed for Cape Lisburne on the north coast where, during the previous summer, they had discovered an open coal mine whose product was fully equal in quality to the Siberian mine at Plover Bay.

Upon arriving at the mine they found almost the entire whaling fleet lying at anchor waiting for the ice to move offshore and open the way to Point Barrow. From them it was learned that the bark *Daniel Webster* had been seen entering the ice, and no further word having been received from her there was considerable anxiety as to her fate. However, no action could be taken until the ice opened up, so the *Corwin* was headed for Herald Island as planned. Before sailing they took on about twenty tons of coal and cleared at 4:00 p.m. on July 28.

The *Corwin* was now far north of the Arctic Circle and headed almost due west across the length of the Arctic Ocean. Her course lay almost exactly on the seventy-first parallel and while they had clear sailing the Polar pack was always in plain sight to the north.

The weather held clear and on July 30 at 5:45 p.m. they entered the ice which surrounded Herald Island, still some twelve miles away. The stanch little vessel worked her way through the ice and at 10:00 p.m. reached the island and made fast to the grounded ice on shore. Wrangel Island was now in plain sight to the west. All hands that could be spared went on shore to conduct a careful search for any records or other evidence that the island had been visited. There were no signs of anyone having been there. They weighed anchor on July 31 and worked their way to clear water. The captain writes in his notes:

I begin to feel as if there is some hope of our getting on W. L. now that we have reached Herald Island.

Now the final dash to their goal was about to start. A course was set for Wrangel Island but they soon encountered heavy ice and were forced to cruise along its edge while keeping a sharp lookout for an open lead. On August 4 they sighted Cape North on the Siberian coast but were unable to land. On the fifth, however, they hauled in for Cape Wankarem and were greeted by two large skin boats loaded with natives who swarmed aboard. The natives immediately recognized and greeted Lieutenants Herring and Reynolds from having seen them with the sledge party and some of the women caused a good deal of merriment by imitating Lieutenant Reynolds as a dog-team driver.

Several days were spent visiting the native settlements, making inquiries regarding the missing whalers and trading with the natives, always with a weather eye to the ice conditions in order to make a quick start as soon as a favorable opportunity presented itself. Conditions turning favorable on the eighth, the *Corwin* got under way again and worked her way along the coast through the heavy sea ice to Cape North. Leaving the coastline there she headed out through the broken ice of the pack and in a few hours was able to reach open water and set a course for Wrangel.

On August 11 the report reads: "By 1:00 a.m. the atmosphere was perfectly clear and Wrangel Island in plain sight about 30 miles distant. . . . The ice pack, which was within half a mile, surrounded us on all sides except between south and southeast by east, in which direction there was open water. A narrow lead of open water also showed toward the northwest as far as we could see from the masthead. We got under way immediately, and, entering this lead steamed in towards the land until 2:30 a.m., when we came to the end of the lead, but the drift ice still being open, we continued on until 4:00 a.m., when the ice, which had been gradually getting closer as we approached the land, became so densely packed that it was found to be impossible to force the vessel any farther. . . . After making several ineffectual attempts to force our way in closer to the land, and finding it impossible, we reluctantly turned our backs on it and pushed out for clear water to wait for a more favorable chance. The ice was so closely packed around the vessel that the operation of turning around, assisted by steam and sail, poles, and small spars to push against the ice, and all means at our command, occupied just one hour. . . . Although sadly disappointed at the failure of this third attempt this season to reach



the land, I felt relieved to be in clear water, and did not despair of ultimate success."

The movement of the ice due to the set of the currents made it necessary to change positions several times during the night. At 4:30 a.m. the *Corwin* again entered the ice and this time with all preparations made to reach the land by crossing the ice if necessary, using the sledges and taking along the skin boat for crossing any open leads that might be encountered. However, as they fought their way closer to the land ice conditions improved. Inside the ten-fathom curve they found much of the ice aground while the floating portion was drifting past and occasionally shooting up over the top of the grounded pieces. Navigation under these conditions was neither comfortable nor safe, but they all felt that the land was now actually within reach and they pushed on. The captain's notes for that important day (see figure 3) read:

Friday, August 12, 1881. Lat 71-04 Long. 177 40 off Wrangle [sic] Land. Got under way at 4:00 a.m. and steamed in toward the end of the lead and into the ice at 7:00 a.m. After a good deal of bumping and squeezing we reached the land and anchored in a small clear space off the mouth of a small river. Went on shore and took possession in the name of the U.S.

This landing unquestionably established a valid claim to the area on the part of the United States. Muir in his text says, "A notable addition was made to the national domain when Captain Calvin L. Hooper landed on Wrangell Land and took formal possession in the name of the United States." Later the great Arctic explorer Vilhjalmur Steffansson in his book, *The Adventure of Wrangel Island*, describing an expedition undertaken in 1921 wrote, "... following 1881 . . . the island was United States territory."

Many years later the Soviet claimed that Lieutenant Wrangel had actually discovered the island but unfortunately for their claim, Wrangel himself in his book, *The Narrative of a Voyage to the Polar Seas in the Years 1821, 1822, and 1823*, which was written long enough after his experiences so that he had plenty of time to make any changes or corrections, wrote "with a painful feeling of the impossibility of overcoming the obstacles with which nature had opposed us, our last hope vanished of discovering the land which we yet believe to exist . . . we had done what duty and honor demanded, further attempts would have been absolutely hopeless and I decided to return." Wrangel located on his chart "from native report" the land which "we believe to exist" but he placed it some distance west of where it actually turned out to be located.

As soon as the official shore party had completed the formalities of discovery, a careful search was made along the shore in each direction for evidences of a landing of any kind. After several hours of searching it became impossible to remain at anchor any longer and a gun was fired to recall all shore parties. Leaving an American flag flying and a complete record of their visit the *Corwin* now worked her way out to the lead.

She was soon in open water and making all speed with steam and sail across the Arctic Ocean but this time with the Polar ice on her port beam. Having found no records of the *Jeannette* on either Herald Island or Wrangel Island, for the very good reasons as we now know that the De Long party had never touched on either of them, the *Corwin* was hastening to Point Barrow in hopes of rendering assistance to the *Daniel Webster* in case she was still in the ice. On the way, however, they spoke the whalers *Howland* and *Rainbow* and learned from them that the *Daniel Webster* had been crushed in the ice and that part of her crew had reached Point Barrow. The remainder were supposed to still be on the pack. Upon learning this the *Corwin* skirted the Alaskan coast line closely and kept a careful watch for signs of any who might have reached the land before the ice went offshore. Constant contact was also made with the native villages along the way and many reports of the wreck were received, all of which were in some agreement.

Point Barrow was reached on August 16 and several whalers which had arrived only a few hours earlier, were found at anchor there, the ice having gone offshore the previous evening. The crew of the *Daniel Webster* were all at Point Barrow and every man accounted for. They were divided up among the whalers except for nine men who had their fill of whaling and "wanted out." These were taken on board the *Corwin* to be returned to civilization and extra supplies were distributed to the other ships to allow for the extra hands taken aboard.

While the *Corwin* was at Barrow the bark *Legal Tender* arrived, bringing the first mail they had received since leaving San Francisco, the *Legal Tender* had sailed from there on June 11. Since she was leaving at once, loaded with surplus bone and oil from the whaling fleet, the crew of the *Corwin* sent mail sacks aboard for their dear ones at home.

On August 19 the *Corwin* sailed for Cape Lisburne hoping to again take coal from the mine, but a strong northeast wind had kicked up such a sea that boating coal was out of the question. The night of the nineteenth was the first night that could be called dark, until then the nights had merely been long twilights. On August 22 they passed close to the Diomedes but never saw any part of them on account of



the thick fog that lay on the water; their presence was well announced, however, by the screaming of the thousands of sea birds that inhabit the rocky cliffs of the islands.

The *Corwin* headed for Plover Bay sometimes under steam and sail and sometimes under sail alone, as they had only about enough coal for one night's run; in fact, when she reached the bay there was only one ton left in her bunkers. While there they took on coal and water and completed minor repairs to their rudder. They got under way on August 27 and headed again for Cape Serdz in order to pick up the dogs and other property left earlier in care of the natives.

On the way the *Corwin* encountered a full gale which broke the fastenings of the icebreaker. Since the seas were running so high that it could not be taken aboard without great danger to the crew, orders were given to cut it adrift to save the bow from being battered by it in the heavy seas. All day on the twenty-eighth both Herald Island and Wrangel Island were in plain sight, but the pack had closed around them.

A course was now laid for Saint Michaels where coal and water were taken on and some of the extra supplies were returned to the Alaska Commercial Company. The *Corwin* set sail on September 17 and reached Unalaska on the twenty-third, the entry for the day reads: **Friday, September 23** Unalaska—Weather fine—landed all extra rations received from the A. C. Co at St Michaels, cabin and wardroom stores. Also sold a lot of extra cabin stores. All hands at work stripping off the remainder of the sheathing, and cleaning ship generally.

Several days were spent cleaning and painting and finally at noon on October 4, the *Corwin*, with a homeward-bound pennant long enough to reach from the masthead to the water, floating in the Arctic breeze, took the schooner *Kodiak* in tow and made her way through the pass before releasing her tow and finally starting the long voyage home.

After five months of continuous battle with the elements it would seem fitting that this last two-thousand-mile leg of her journey should be smooth sailing. Such, however, was not to be the case for the sea was to make one last attempt to gain a victory. On October 5 the wind increased to a strong gale from the northeast, the seas ran very high, and in her struggles the *Corwin's* bobstay parted and her bowsprit was carried away. All hands were put to clearing away the wreckage and as soon as the storm abated somewhat a small spar was rigged as a temporary bowsprit so that she could carry her headsails and make a proper appearance on reaching her home port. The *Corwin* had to buck strong head winds and foul weather until the nineteenth.

On October 20 we come to a significant entry in the captain's private notes. This record had been faithfully kept every day since the first of the year. All through the period of anticipation wondering whether the *Corwin* would be given the assignment, through the time of preparation, and finally on the entire voyage in fair weather and foul, not a single day had been missed. Now the *Corwin* had rounded Cape Mendocino on the California coast and was feeling her way toward San Francisco Bay in a dense fog. All hands on deck were straining ears and eyes to locate a bearing, if only the low moan of the giant foghorn guarding the entrance to the bay. The entry for the day reads:

Thursday, October 20 Still trying to get into S.F., thick all day, caught a glimpse of the hills . . . also saw a number of vessels.

Here the record ends; there is no further entry of any kind. To one who is familiar with the fogs that blanket the Bay Region at certain seasons the picture is plain enough. After being enveloped in an impenetrable mist and not caring to risk the dangerous channel by compass alone, suddenly as though some gigantic door had opened, the *Corwin* emerged from the fog and before her, warm in the golden California sunshine lay the brown hills of Marin County and the Golden Gate with welcoming arms outstretched. Beyond lay homes and loved ones and surcease from the relentless battles against the Arctic. No further entries were needed.

No more fitting close to the account of the cruise of the *Corwin* could be made than to quote from Captain Hooper's report his remarks about the fate of the *Jeanette*.

"In closing my report of the cruise of the *Corwin* I cannot refrain from making brief reference to the fate of one of the objectives of our search . . . the *Jeanette* and her officers and crew . . . I desire to express my unbounded admiration for their fortitude and their heroic exertions in making the most remarkable retreat over the ice ever made by man, from where their vessel sank to the Lena Delta, for their brave struggle for existence after reaching land, and their cheerful resignation to fate when death in its most awful form stared them in the face and claimed them one by one."

More than seventy years have passed since the little shore party from the *Corwin* effected the first landing on Wrangel Island and took possession in the name of the United States. Blasted by Arctic gales and searred by the polar pack it still lies surrounded by frozen seas, a land which at the time of its discovery seemed inaccessible and valueless, it now lies directly across the most direct air routes between the capitals of Europe and those of the Western Hemisphere.



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